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Operational Efficiencies of Mobile Inspection

Truck Inspection System Study

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Ministry of
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Communications

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Planning and
Research Division

TRE-81-08

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FOREWORD

This report is one of a series of projects studying the Ontario Truck Inspection System. The other projects deal with conviction profile, compliance rates, inspection station efficiency and behavioural/economic factors in compliance.

TRE-81-05 "Truck Regulation Violations"
TRE-81-06 "Truck Compliance Rates"
TRE-81-07 "Operating Efficiency of Inspection Stations"
TRE-82 - "Behavioural and Economic Factors in Compliance"

This report provides a description of the efficiency impacts of changes in mobile operating procedures and/or resources.

The model has had limited, successful testing in field applications. The reader is cautioned that, as with most models, the output is only as reliable as the input. Hence, the reliability of the results will be subject to vagaries in the data on traffic volume and compliance rates.

Mr. A.C. Agarwal served as Project Manager and co-author until August, 1981, when he left the Ministry. This report reflects his contribution and editorial comments.

Richard Slocum
Study Director
November 1981

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CONTENTS

	Page
FOREWORD	ii
ACKNOWLEDGEMENTS	iii
EXECUTIVE SUMMARY	viii
1/ INTRODUCTION	1
1.1/ The Mobile Inspection Setting	2
1.2/ Definitions of Operational Efficiency	7
1.3/ Inspection Situations to be Studied	8
2/ BASIC APPROACH	10
2.1/ Parameters	11
2.2/ Assumptions	13
2.3/ Operational Times	14
2.4/ Approach for Irregular Truck Arrivals	17
3/ SCENARIO #1 -- PAPER CHECK ONLY	20
3.1/ Calculations	21
3.2/ Graph Interpretation	24
3.3/ Efficiency Charts	25
3.3.1/ Figure 6 Observations	25
3.3.2/ Figure 7 Observations	26
3.3.3/ Figure 8 Observations	27
3.3.4/ Figure 9 Observations	29
3.3.5/ Figure 10 Observations	30
3.4/ General Observations	30
4/ SCENARIO #2 -- PAPER AND WEIGHT CHECK	31
4.1/ Calculations	34

CONTENTS (cont'd)

Page

4.2/ Efficiency Charts..... 36
4.2.1/ Figure 12 Observations..... 37
4.2.2/ Figure 13 Observations..... 37
4.2.3/ Figure 14 Observations..... 38
4.2.4/ Figure 15 Observations..... 39
4.2.5/ Figure 16 Observations..... 40
4.3/ General Observations..... 41

5/ SCENARIO #3 -- MECHANICAL INSPECTION 42
5.1/ Description..... 42
5.2/ Empirical Data..... 46

6/ OTHER SCENARIOS 49

7/ SUMMARY AND CONCLUSIONS 53

8/ REFERENCES 57

APPENDIX 1/ COSTS BREAKDOWN FOR MOBILE INSPECTION 78

APPENDIX 2/ VIOLATION RATES FOR SPECIAL 1980 SURVEY LOCATIONS ... 80

APPENDIX 3/ TABLE OF TIME LOSS VALUES 82

LIST OF TABLES

		PAGE
1/	Efficiency Behaviour Scenario #1 -- Paper Check Only	x
2/	Scenario #2 -- Paper & Weight Check	x
3/	Trends Between Efficiency and Major Influencing Variables	xi
4/	Scenario #1 Unit Processing Times	58
5/	Scenario #2 Unit Processing Times	59
6/	Mechanical Inspections By District For the Period 80-04-01 to 80-12-26	60
7/	Summary of Roadside Mechanical Inspections By District For the Period 80-04-01 to 80-12-26	60
8/	General Trends Between Parameters & Efficiency Measures	61

LIST OF FIGURES

1/ Flow Chart Showing Functions of a Highway Carrier Area Inspector (one man) 62
2/ Flow Chart Showing Functions of a Motor Vehicle Inspection Unit Only 63
3/ Flow Chart Showing Functions of a Combined Highway Carrier and Motor Vehicle Inspection Squad..... 64
4/ Analytical Process 65
5/ Flow Chart for Scenario #1 -- Paper Check Only 66
6/ Relationship Between Inspection Capacity and Average Truck Volume for Paper Inspection Only Scenario 67
7/ Relationship Between Inspection Capacity and Staffing Level for Paper Inspection Only Scenario 68
8/ Relationship Between Number of Trucks Inspected and Staffing Level for Paper Inspection Only Scenario 69
9/ Relationship Between Detection Efficiency and Average Truck Volume For Paper Inspection Only Scenario 70
10/ Relationship Between Detection Efficiency and Infraction Rate For Paper Inspection Only Scenario..... 71
11/ Flow Chart For Scenario #2 -- Paper and Weight Check..... 72
12/ Relationship Between Inspection Capacity and Average Truck Volume for Paper and Weight Inspection Scenario..... 73
13/ Relationship Between Inspection Capacity and Detection Expertise for Paper and Weight Inspection Scenario..... 74
14/ Relationship Between Inspection Capacity (Paper Only) and Inspection Rate for Paper and Weight Inspection Scenario. 75
15/ Relationship Between Detection Efficiency and Truck Volume for Paper and Weight Inspection Scenario..... 76
16/ Relationship Between Detection Efficiency (Paper Only) and Infraction Rate for Paper and Weight Inspection Scenario..... 77

EXECUTIVE SUMMARY

This report examines the operational efficiencies of MTC's mobile truck inspection units. It was undertaken as an essential element in the overall study dealing with evaluation of the total truck inspection system.

The study involves qualitative description of the processes involved, quantitative analysis relating to efficiency measurement of selected operational situations, and the development of an efficiency problem solving methodology for application to specific cases of efficiency estimation.

The core of the analysis develops those scenarios identified as the basic concentrations of enforcement activity -- paper check, paper and weight check, and mechanical check. For the two highway carrier scenarios, formulae are used to derive efficiency measures which are subsequently used to develop an exemplary set of "efficiency charts". Following are the efficiency measures used:

i/ inspection capacity, which is defined as the proportion of hourly truck volume inspected;

ii/ detection efficiency, which is the ratio of hourly detected violations to hourly expected violations.

Two other components of efficiency, namely time delay to trucks and cost to MTC, are not considered in terms of efficiency.

A computer program capable of estimating the efficiency measures has been developed for the highway carrier scenarios and is operational. Data input requirements include a description of the inspection process to be conducted, hourly truck traffic volume and the expected non-compliance rate at the contemplated inspection location. The program is then capable of estimating hourly efficiency measures for various staffing levels. With the development of a user's manual, managerial capabilities in the field could be strengthened by taking advantage of this predictive tool.

It was found that detection efficiency increases as staffing level or expertise increases. On the other hand, detection efficiency decreases with increasing traffic volume or infraction rate. Measurement of efficiency, in terms of capacity, reveals a similar behaviour in relation to the influencing variables, except in the case of increasing inspector's expertise, which reduces capacity slightly. The following three tables compare efficiency behaviour in response to variation in the influencing variables, both in terms of approximate magnitude and also by general direction of relationship.

The usefulness of this study is in certain respects limited. Data, operational time values and rates of infraction are difficult to predict in certain cases. In addition, the assumptions on which the analysis is based must be appropriate for the situation at hand. The most critical limitation relates to the interpretability of the derived efficiency values. They should not be considered as absolute measures, but rather in accordance with the parameter values and assumptions on which they are based. The numerical values are intended only as approximations.

Mobile inspection is a flexible activity by virtue of its mobility and its highly labour-intensive nature. Flexibility results in a less structured and therefore less efficient process in comparison to fixed stations. However, flexibility may simultaneously result in increased effectiveness. Evaluation of mobile inspection effectiveness is beyond the scope of this study, since it involves gauging the violator perception of different forms of inspection.

Table 1/ EFFICIENCY BEHAVIOUR
SCENARIO #1-- PAPER CHECK ONLY

CONDITIONS				EFFICIENCY MEASURE	
No. of Inspectors	Truck Volume/hr	Infraction Rate	Expertise Level	Inspection Capacity (%)	Detection Efficiency (%)
1	25	4%*		18	36
2	25	4%	F_e = 2**	52	100
3	25	4%	"	80	100
4	25	4%	"	100	100
1	100	4%	"	5	10
2	100	4%	"	16	32
3	100	4%	"	24	48
4	100	4%	"	32	64
1	25	8%	"	17	34
2	25	8%	"	48	96
3	25	8%	"	76	100
4	25	8%	"	100	100
1	100	8%	"	5	9
2	100	8%	"	15	29
3	100	8%	"	22	44
4	100	8%	"	29	59

Table 2/ SCENARIO #2 -- PAPER & WEIGHT CHECK

CONDITIONS					EFFICIENCY MEASURES	
		Infraction Rate				
No. of Inspectors	Truck Volume/h	Paper	Weight	Expertise Level	Inspection Capacity (%)	Detection Efficiency (%)
1	25	6%*	6%*		12	25
2	25	"	"	F_e = 2**	31	62
3	25	"	"	"	45	93
4	25	"	"	"	65	100
1	100	"	"	"	3	7
2	100	"	"	"	9	17
3	100	"	"	"	13	26
4	100	"	"	"	17	35
1	25	10%	10%	"	11	22
2	25	"	"	"	28	55
3	25	"	"	"	41	83
4	25	"	"	"	57	100
1	100	"	"	"	3	6
2	100	"	"	"	8	15
3	100	"	"	"	12	23
4	100	"	"	"	15	31

* The infraction rates shown here are for illustrative purposes only. Values in the field may differ.

** Refer to Section 2.1(iv) for an explanation of this parameter valuation.

Table 3/ TRENDS BETWEEN EFFICIENCY AND MAJOR INFLUENCING VARIABLES

RISE IN INFLUENCING VARIABLE	EFFECT ON EFFICIENCY MEASURE			
	INSPECTION CAPACITY		DETECTION EFFICIENCY	
	Paper Check	Paper & Weight Check	Paper Check	Paper & Weight Check
Staffing level	↑	↑	↑	↑
Truck volume	↓	↓	↓	↓
Infraction rate	↓	↓	↓	↓

1/ INTRODUCTION

This study deals with the operational efficiency of mobile truck inspection units. An understanding of this topic is one of the requirements for the overall evaluation of the truck inspection system. As such, the study is developed in a manner which correlates itself with the nature and purpose of the overall Truck Inspection System Study.

Mobile inspection should be regarded as a critical component in the enforcement of the Ontario Trucking Regulations. Due to its mobile nature, and flexibility in time and location, it may have potentially high effectiveness. This activity is complementary to the fixed truck inspection station facilities as well as being an enforcement entity in its own right.

The purpose of the study can be broken down into three major objectives, i.e., to provide:

i/ an overview of the processes and activities involved in mobile inspection;

ii/ a developed methodology applicable toward the solution of efficiency related questions for specific situations in mobile inspection; and

iii/ an indication of the general efficiency levels to be associated with selected operational situations found in mobile inspection.

The study first describes the various mobile inspections in a qualitative manner (Section 1.1). This provides a thorough understanding of the scope and range of functions involved in such a flexible activity. Identification and definition of the most commonly undertaken mobile inspection processes is included.

The study then moves toward a more quantitative analysis with the development of a general methodology and analytical process to be used for efficiency calculations (Sections 1.2 through 2.4). One component here is the assignment of operational time values to each of the functions which may be performed in mobile inspection. Reliability and accuracy of the calculated efficiency values largely depends upon the operational time values adopted.

The core of the analysis involves the development of three major scenarios, each of which is intended to represent a commonly practiced mobile inspection process (Chapters 3, 4, and 5). Each scenario will define explicitly the operational situation involved. Formulae are developed where possible and are used for the calculation of various measures of efficiency. "Efficiency charts", which graphically present efficiency levels, are generated from these calculated results. Various trends and relationships between variables are examined in these graphs.

Application of the methodology for the major scenarios to "situation-specific" efficiency estimation is explained. The extension of the developed scenario methodology to minor scenarios is discussed in Chapter 6.

A concluding chapter (Chapter 7) serves to tie together the major points emerging from the analysis, as well as to comment on other relevant questions.

In relation to the overall truck inspection study, the results derived or derivable from the analysis should be quite useful. The general efficiency of mobile inspection can be compared to that of the fixed stations. More importantly, level of efficiency may be used in that subsequent phase of the project which will deal with the attempted estimation of "effectiveness" for the various truck inspection components. In terms of the trucker's perception, the effectiveness of mobile inspection may be substantially greater than is dictated by its actual efficiency level.

It is recognized that the study at hand has several limitations as described throughout. However, the methods and results contained here are useful, provided they are reviewed in light of the assumptions which limit their range of applicability.

1.1/ The Mobile Inspection Setting

Mobile truck inspection is a flexible activity mainly by virtue of its mobility. There can be many variations involving the process itself, manpower employed, and location.

There are two general forms of mobile inspection. One is the "motor vehicle inspection" which involves a check of the vehicle's mechanical fitness by certified mechanics; the other is the "highway carrier inspection". This activity involves the enforcement of weight, size, and licencing regulations by trained MTC or Ontario Provincial Police (OPP) officers, and is the major focus of this analysis. Municipal police forces also participate in highway carrier inspection within their jurisdiction and in fact MTC lends portable scales to the police forces for this purpose. Note that total police involvement is supplementary to that of the MTC officers.

The motor vehicle inspection is more structured than the carrier inspection as there is a set report of checks made which must be filled out for each truck. Of course the inspector(s) may, according to his/their discretion, choose to concentrate on certain components while disregarding others. Motor Vehicle Inspectors (MVIs) may work alone or in pairs. They may work out of a Truck Inspection Station (TIS) facility, at a roadside, at a strategic truck entry point such as border crossings, or in a trucking company's yard. In some cases the MVIs will join with a carrier unit to form a combined enforcement team.

The highway carrier inspection process is highly variable. As many as four Highway Carrier Inspectors (HCIs) may work as one unit. A lone area inspector usually patrols a specific section of the road, stopping and checking suspect trucks. Due to the manpower constraint, an area man is primarily an inspector of the various licences. In a case where he suspects a weight violation, he would most likely escort the truck to a fixed scale location instead of using portable scales. Since the area man may spend considerable time performing non-inspection related functions, estimation of one man efficiency applies only to those hours spent inspecting trucks.

A mobile squad (two, three or four HCIs) is usually positioned at some temporary location. This may be at a roadside so that trucks are flagged down for inspection, or at strategic truck entry points such as border crossings. These squads may use portable scales for weight enforcement as enough manpower is usually available. Note that there exists a substantial distinction between the one-man and squad operation.

There are various inspection functions available to the HCIs (area man or squad). Once a suspect is stopped, there is always a quick visual check as well as a paper check (licences, etc.). Beyond this, there may be measurement of overall dimensions (length, height, width), a check of cargo contents, and/or a weight check and axle spacings measurement. If a violation is detected then a charge report is written up. Most of the efforts are concentrated in paper and weight enforcement with the former receiving more emphasis, at present, largely because of the relative difficulty involved in the use of portable scales for weighing.

As mentioned earlier, highway carrier and motor vehicle inspectors may work together (one, two, three or four HCIs along with one or two MVIs) as a combined team. This combination of activities is potentially important at strategic points such as border crossings where most types of violations (everything but weight) tend to be above average. However, since the two types of inspectors are looking for totally different types of problems, their efforts can, and often do, conflict.

The various activities are best presented as generalized flow-chart type diagrams. Figure 1 shows the inspection process for a highway carrier area inspector. Similar information is given for a motor vehicle inspection unit in Figure 2 and for a combined carrier and motor vehicle crew in Figure 3.

Following are observations made through field research, and opinions made by inspectors regarding the highway carrier mobile inspection process:

- In order to inspect as many suspect trucks as possible, a mobile squad may, during the course of a shift, perform area and spot-location inspections alternately.

- The following situations may be termed dangerous in terms of stopping suspect trucks:
  i/ high volume roads,
  ii/ high speed roads,
  iii/ tail-gating trucks at any volume or speed.
  These factors make it difficult for the inspector(s) to act

promptly. The suspect may be followed and stopped at a location where it is safe to do so, or he may not be stopped at all.

- The officer must know his working area very well in order to reach reported suspects at specified locations.

- Except in cases where trucks are forced to pass an inspection location, trucker use of Citizens' Band (C.B.) radio allows all trucks in the area to know, almost immediately, where the inspection unit has set-up. Therefore there is a need to change location frequently.

- If an HC inspector finds a suspected mechanically unfit truck, he may radio in for an MVI who comes out to investigate and take appropriate action.

- The infraction rate of PCV violation among two-axled vans in the Metro Toronto area seems to be very high. Therefore, they are a special area of concentration for the mobile inspectors in that area.

- Drivers admit to the inspectors that the risk of paying a fine is incorporated into normal operating costs, and is therefore considered simply as another business expense. This behaviour on the part of the knowing violator suggests that the benefit derived through violation provides greater economic value than does the avoidance of monetary penalty by conforming to regulations.

- Adverse weather conditions, naturally, affect the mobile inspection process in a negative manner.

- Mobile inspection would be aided greatly if shoulder-of-the-road "inspection pads" were built into roads at interval locations (these would be paved lay-bys where trucks could be pulled off safely). In fact, a few of these have been built in Ontario.

- The efficiency of certain mobile units could be increased by providing the team with a small van rather than a car. The van could

contain desk and photocopier which would greatly facilitate the processing of violators.

The present situation, in terms of infraction and detection rates for mobile inspection, is not well understood. However, Read, Voorhees & Associates have done some work in this area [3]. The estimated percentage of trucks inspected by a given mobile unit ranges from 0.3 to 3.0. The violation rates observed through 23 survey sites are shown in Appendix 2 which is entirely reproduced from the Read, Voorhees & Associates study. The study properly emphasizes that the violation rate varies greatly by location and time. Despite the restricted sample size, if the survey results are assumed to be approximately indicative of existing rates, then weight violation varies from 0.0 to 14.53% with a mean value of 3.53%. The "all other violations" category (i.e., mostly papers) varies between 0.82 and 16.22% with a mean value of 6.61%. These values have been used as a general guide for selecting a relevant range of values for the infraction rate variables in this study.

The following observations were made:

- Special survey violation rates were found to be higher on "other King's Highways" (where mobile activity is concentrated) than on freeways.

- Lowest violation rates were found in the Central and Southwest Regions.

Unlike the case of TISs, comparisons between infraction rate found by special survey, and the historical detection rate of a particular location, are practically impossible for mobile units. Unlike inspections at permanent stations, mobile inspection is not carried out consistently at an exact location. Therefore, while the Read, Voorhees and Associates study provides a measure of infraction rate at 23 particular mobile inspection locations, detection performance at those points remains unknown.

Clearly, the lack of historical detection rates for specific locations lends legitimacy to the theoretical approach adopted in this study.

In regard to mechanical vehicle inspection, there has been no recent attempt to randomly sample the total truck population for mechanical defects. A restricted random inspection procedure was undertaken by the MTC D&V Regions in 1974 and 1975. Results of that survey are now, unfortunately, dated. A similar survey at anytime in the future would be extremely useful in helping to determine the mechanical defect rates for the total truck population. Note that the MTC Programme Administration Office of the Regional Operations division has defect rates by numerous types of breakdown, but only in terms of the inspected truck population. Despite the availability and sophistication of this data, their results cannot be extended to represent the total truck population.

1.2/ Definitions of Operational Efficiency

For purposes of this study, "efficiency" may be considered in terms of any one of the following:

i/ Inspection Capacity is a measure intended to reveal the number of trucks which an inspection unit can process per time period. Inspection capacity can be defined in either of two ways -- one absolute and one relative measure:
a/ total number of trucks inspected per hour, and
b/ fraction of total truck volume inspected.

The relative value (b) is more useful because it gives an idea of the truck volume that passes by without inspection.

ii/ Detection efficiency is expressed as the ratio of violations detected per hour to violations expected per hour. This measure reflects an inspection unit's ability to detect violations. It is an excellent measure of efficiency in that it deals only with that segment of the truck population for which enforcement is intended. Note that the precision of this measure depends on the accuracy of the "expected" value.

iii/ Time delay to the truck operator is undesirable as time means money to the truck operator.

Having to undergo truck inspections increases the time required by an operator to move cargo from point A to point B. Therefore it would be desirable to minimize time loss due to inspection for non-violators. On the other hand, an added incentive to obey regulations could be established by forcing detected violators to spend longer in the inspection process. Non-violators are given the benefit of a shorter time loss, while offenders are subjected to a more extensive inconvenience. In fact, this applies to a large extent at present. It takes longer to process violators because charge reports have to be written up. Or in extreme cases of time loss, a violator will be pulled off the road until a serious problem is corrected on the spot.

iv/ There is also a cost to MTC. Mobile enforcement involves a monetary expense for the Ministry, which can be measured per unit, per shift, or per truck inspected. The cost breakdown for mobile inspection is presented in Appendix 1.

Out of the four definitions of efficiency presented here, (i) and (ii) are more appropriate for our needs.

1.3/ Inspection Situations to be Studied

It has been shown that the character of mobile inspection may vary substantially. The analysis of one general process intended to represent all components of mobile inspection would be unrealistic and could lead to meaningless results. In reality, there are several well defined areas of enforcement which are constantly and appropriately emphasized. It is these major spheres of inspection activity with which we are concerned here in terms of critical analysis.

Three scenarios are developed herein, each intended as an acceptable representation of the most common existing operational situations. The three scenarios are:

i/ licences or "paper" regulation check,
ii/ paper and weight regulation check,
iii/ mechancial fitness check.

Scenarios are developed for each of these in Chapters 3, 4, and 5, respectively. Each scenario contains a precise definition of the activity, a developed analytical process, and a set of exemplatory "efficiency charts" which will serve to reveal the workings of the underlying variables as well as the general levels of efficiency.

Of course, several other situations could be examined in order to account for all the functions which the inspecting officers may be called on to perform. However, it is our belief that the remaining components of mobile inspection are peripheral and as such do not warrant an in-depth evaluation. The secondary scenarios are nevertheless presented in definitional form in Chapter 6.

2/ BASIC APPROACH

This study is, simply, a theoretical analysis critically based upon a set of observed real operational time values. The only exception to this general approach is found in the "mechanical inspection only" scenario where a less rigorous exercise is conducted by necessity.
The reason for this is explained in Chapter 5.

A theoretical approach was chosen over one based on empirical observation primarily because the amount of field data required to achieve reliable measures of reality was not feasible.

The methodology employed involves the generation of an expected sequence of events and the associated allocation of inspection resources to them -- all are subject to the constraint of time. Measures of inspection efficiency can be derived by determining the events which should occur on average and the amount of time required to deal with them. By varying the parameter values over a range relevant to the mobile inspection process, efficiency measures are obtained for each possible combination of variable values.

The analytical process is more specifically defined in Figure 4. Given the parameters inherent in a specific scenario, the necessary calculations can be performed, systematically, in the following sequence.

i/ The "unit processing time" for each possible event (i.e., for each possible category of truck in that scenario) is established. For each truck category, a time value is assigned to each operational activity. The sum of all subfunction times represents the unit processing time for the particular violation category.

ii/ The procedure for the modification of the unit processing times which reflects the phenomenon of irregular truck inter-arrivals is explained fully in Section 2.4.

iii/ A calculation of expected infractions in the violation categories plus the non-violation category.

iv/ There is also a calculation of the total hourly truck volume inspected in their respective categories. Corresponding hourly time values are also computed.

v/ The desired ratios are calculated from the various generated values. Two of these ratios, which serve as good measures of inspection efficiency, are:

a/ Inspection Capacity = $\frac{\text{hourly truck volume inspected}}{\text{average hourly truck volume}}$

b/ Detection Efficiency = $\frac{\text{hourly violations detected in a given category}}{\text{hourly expected infractions in that category.}}$

The analysis is intended to yield results which while certainly being general indicators of reality, should not be interpreted as absolute. During the course of the analysis, various assumptions have been adopted. It is believed that the assumptions chosen are reasonable and well founded. However, in many cases alternative assumptions would be just as appropriate. This is especially relevant in terms of the operational time values upon which the analysis framework is based.

Calculations are conducted on a per hour basis in terms of inspection. Furthermore, it is assumed that the hour is used entirely for performing basic inspection procedures as opposed to peripheral functions such as driving to and from the inspection location and setting up portable scales. Therefore, one could not simply multiply the derived hourly results by the number of hours in one shift and hope to get an accurate estimate of efficiency per shift. It should be recognized that auxiliary functions are essential to the process in total, but are not part of inspection as such.

2.1/ Parameters

The variables which influence efficiency and dominate the analysis are listed and defined below:

i/ The Staffing Level of the HCIs and MVIs is measured by the number of inspecting officers. One, two, three and four man highway-

carrier crews and one or two man motor-vehicle crews are considered here. The two types of inspectors may be working in separate or mixed groups.

ii/ The Average Truck Traffic Volume (V), as a variable, is expressed as the average number of trucks travelling on the highway in the direction being inspected, per hour. Values of 10, 25, 50 and 100 are considered. Higher volumes are not considered, since mobile units are used almost exclusively on routes in this traffic volume range.

iii/ The Infraction Rates for Paper (I_p) and Weight (I_w) have been estimated in a separate study conducted by Read, Voorhees & Associates Ltd. [3]. Given the infraction rate, the number of expected violations on the roadway can be derived for any truck volume level. Infraction rates for mechancial fitness are unknown at this time.

Values of 0.02, 0.04, 0.06, 0.08, 0.10, 0.15, and 0.20 are used at various points in the scenario development.

iv/ Another factor is the Inspector's Level of Detection Expertise (F_e). It became evident very early in the research for this study that the experience which an inspector possesses may be an important factor in detection efficency. The officers may learn who and what to look for in their search for violators. This expertise includes both a general knowledge and an element of familiarity with the traffic in a specific area.

This expertise factor is applied to the infraction rate so that the resulting detection efficiency reflects the human benefit of experience as well as the prevailing rate of violation.

The value of F_e is set at either 1, 2, and 3 -- depending on the inspector's experience from the total truck volume. A value of $F_e = 1$ indicates no previous screening experience. The value of F_e indicates the multiple by which the "number of detected violators" increases due to inspectors' growing expertise. These

values are yet to be verified and are subject to adjustment upon collection of field data. If experience/expertise is unknown, use $F_e = 1$ in the calculations. The purpose of using a range of 1 to 3 for the value of F_e is to permit a sensitivity-type analysis, i.e., to model the variations that might actually occur in actual situations.

2.2/ Assumptions

Following are the major assumptions which enter the analysis at various stages:

i/ The Operational Time Values represent the time requirements of the various functions which an inspector may be called on to perform. These can vary substantially from one situation to the next. In some cases, an average value has been used. In other cases, however, it is practically impossible to derive such a representative mean value. In the latter situations, it becomes necessary to assume a very strictly defined function to which a time value can more appropriately be attached.

Any assumptions dealing with operational time values will be documented in the scenarios where they apply.

ii/ An Inspection Process is defined for each scenario. It is necessary to assume a well defined process or a number of variations thereof. Every subfunction of an inspection routine must be considered in order that a realistic time value can be assigned to the process in total.

In each of the scenarios developed here, the processes chosen are defined explicitly.

iii/ Truck Inter-arrival Time is unpredictable as trucks do not arrive at regular intervals. If they did, an inspector could find trucks regularly for the purpose of inspection. However, due to irregular truck arrivals, there may be times when the inspector has to wait for trucks to arrive. At other times, a number of trucks may

arrive simultaneously and the inspector will have to miss many of them. The irregular arrival is especially important at low truck volumes.

The solution to the phenomenon of irregular truck flow is presented in Section 2.4.

iv/ The same logic as in (iii) applies to Violator Inter-arrival Time. We will assume a regular rate of arrival for violating trucks throughout the analysis. This is justified by the fact that the effect of randomness should be captured by modelling total truck flow as irregular. Therefore, the amount of analysis refinement that could be achieved by assuming irregular violator inter-arrivals is apparently minimal. The small increase in analysis sophistication would not justify the increased level in analytical complexity which would be required to achieve it.

v/ It is assumed that the observed Detection Rate (i.e., detection of infractions) is a function not only of the infraction rate but also of the inspector's level of detection expertise, if volume is high enough to require an inspection decision.

vi/ Establishment of Truck Configuration may be necessary as certain scenarios require that a specific truck type (in the physical sense) be assumed in order to better assign time values to various subfunctions of an inspection process. Generally speaking, a large truck with more axle units requires more time to perform such tasks as measurements and axle weighings. Where a specific truck must be defined, the 3 S2 type is assumed.

2.3/ Operational Times

As noted in Section 2.3, the time value assigned to each of the numerous subfunctions which may be performed by the inspector(s) during an inspection is an average figure wherever possible. In other cases, a range of values must be used instead.

Listed here are the time values for each of the inspection tasks:

1. The time required to stop a vehicle depends on the method used by the inspector(s). It could range from 1 min for a roadside flag-down stop to 5 min if the truck is chased down. There also exists a stopping procedure whereby the inspector(s) wait(s) for a specific suspect down the road from where first spotted. In such cases the unit may have to wait up to several hours and during this time is unable to stop other suspects, so as not to risk missing the primary objective.

2. Visual check time is 2 min.

3. The time required for overall dimension measurements is 2 min or more, depending on the size of the truck unit.

4. The time required for paper check (licences, permits) is 2 min for straight licence check but up to 5 min for a more thorough inspection and/or if the trucker has difficulty finding all his papers.

5. The time required for load check is 3 min.

6. The time required to set up portable scales is 15 min. This applies only once per shift for a squad stationed at a temporary location and once per weight inspection for a roving area unit.

7. The time required to weigh a truck on portable scales critically depends on the truck driver's ability. The following value may be taken as a general indication: 67 s per axle unit (40 s per single axle and 94 s per double axle).

8. The time required to measure axle spacings is 20 s per measurement.

9. The time required to escort a truck to the scale location varies with the situation:

i/ Portable scales which need a fairly large and firm area in order order to weigh trucks properly may, necessarily, be set-up somewhere other than the flag-down point. The time required is from 5 to 30 min.

ii/ Escorting the truck to a permanent scale at a TIS or private firm may be necessary in order to verify findings of the portable scales, or more commonly to weigh a suspected violation for the first time. The time required for this is from 5 to 40 min.

10. The time required to write up an Ontario Highway Traffic Act (HTA) report is 15 min.

11. The time required to write up an Ontario Public Commercial Vehicles Act (PCV) report is 8 min.

12. The time required to write up an Ontario Public Vehicles Act (PVA) report is 8 min.

13. The time required to remove plates from a truck that is to be detained is 2 min if tools are available to the inspector.

14. Five to 15 min is required to escort a truck to a nearby service station if it is found unsafe after a MV inspection (or HC visual inspection).

15. The time required for a MV inspector to conduct mechanical inspection and write up his report is 20 min for one man, 15 min for one man aided by a HCI, and 13.5 min for two men, although this varies with the type of truck unit.

16. A squad (or area man) requires 15 to 60 min to reach or change the inspector location. Note, however, that this is not wasted time since the inspector(s) is (are) constantly looking for possible violators.

17. The time required for a carrier inspector to help a MV inspector is 5 min per mechanical check.

18. A MVI takes 4 min to issue a CV 3 form.

19. It takes a MVI 15 min to make a charge under the HTA and to write up a provincial offences report.

20. A "between inspections break" requires 1 min.

2.4/ Approach for Irregular Truck Arrivals

The assumption of a regular truck inter-arrival rate is clearly unrealistic when considering lower average flow volumes as is the case here. For this reason we now proceed to relax the regularity assumption, in order to increase the level of sophistication of the analysis, and in so doing draw closer to the "real world" situation.

The random arrival of trucks can be modelled in terms of probability by using the Poisson distribution formula:

$$P(X) = \frac{m^{x} e^{-m}}{x!} \qquad (1)$$

where $P(x)$ = probability of x trucks arriving in a specified time interval

m = average number of vehicles arriving per interval (i.e., hourly volume divided by number of intervals per hour)

e = base of Napierian logarithms = 2.71828

$$\therefore P(0) = \frac{m^{0} e^{-m}}{0!} - \frac{1.\left[\frac{1}{2.71828^{m}}\right]}{1}$$

If the event of "x truck arrivals" in one time period (equals 30 s here) is assumed to be statistically independent of "x truck arrivals" in all

other such time periods, then the random number Y of s) trials required to obtain the first "success" (i.e., χ truck arrival has a geometric distribution with parameter $P(\chi)$truck arrivals).

Now, the expected number of trials which must be made until a "success" (χ truck arrivals) is observed, when the random variable Y has a geometric distribution with parameter $P\ (\chi)$ is

$$\mu_y = \frac{1}{P(\chi)} \qquad (2)$$

In our situation, a "success" may be termed as the event of "one or more truck arrivals". Therefore, the expected number of trials which must be made in order to obtain the first success is

$$\mu_y = \frac{1}{1 - P(0)} \qquad (3)$$

For example, if P(0 truck arrivals) = 0.5, then

$$\mu_y = \frac{1}{1 - .5} = 2$$

This value represents the maximum number of specified time periods which will elapse on average before one or more trucks arrive. If the specified time interval equals 30 s, as it does here, then 2 x 30 = 60 s = 1 min will elapse. We now know the average maximum amount of time that the inspector(s) will have to wait from the time they are ready for his/their next inspection to the time a truck arrives.

Refer to the table in Appendix 3 for values of average maximum time loss for all (even) levels of average hourly truck volume between 10 and 100. When working through an efficiency calculation using the model, the time loss value corresponding to average hourly truck volume on the roadway in question must be extracted from Appendix 3 for input into the calculations.

By adding this average time value to the unit processing times for each of the truck types (i.e., violation and non-violation categories) arriving, we get new unit processing times which now vary with volume per hour.

The problem of irregular truck flow has been translated here in terms of additional time loss per inspection. Alternatively, this phenomenon could have been treated by means of a computer simulation model.

By using the method described above, truck inter-arrivals will be treated as irregular throughout this study.

3/ SCENARIO #1 -- PAPER CHECK ONLY

This scenario deals exclusively with the single most widely performed function in mobile inspection -- the licences or paper check. This operation is totally within the domain of highway carrier inspection. Either an area man or a squad unit can conduct this activity. The checking of licences and registrations lends itself well to mobile inspection since there is a minimal manpower requirement and no use of mechanical aids.

There are three basic subfunctions inherent in the process, each having its own average time requirement:

i/ Stop Truck, 1 min
ii/ Visual Check, 2 min
iii/ Paper Check, 2 min

A short, between-inspections break for the officer (1 min) is given to yield a total average "unit processing time" of 6 min per non-violating truck. When a violation is detected, 8 min are required for the inspector to write up the PCV report needed for charging a violator of any (PCV) regulations. The total process of this scenario is presented schematically in Figure 5. Note that an HTA-related problem may be detected when the inspector conducts a quick visual check of the truck. Obvious defects such as broken tail-lights could be found.

Having defined the process, we can now set down the required assumptions for the analysis:

i/ irregular truck inter-arrivals (see Section 2.4 for a complete explanation of the method used);

ii/ regular violator inter-arrivals;

iii/ no motor vehicle inspection involved; and

iv/ detection rate as a function of both the paper infraction rate of the total truck population and the inspector's level of detection expertise.

The four parameters used and their values are:

i/ average hourly truck volume; V = 10, 25, 50, 100
ii/ number of highway carrier inspectors; HCI = 1,2,3,4
iii/ paper infraction rate; I_p = 0.04, 0.08, 0.15, 0.20
iv/ inspector's expertise factor; F_e = 1,2,3.

3.1/ Calculations

The time required for processing or "unit processing time" is:
i/ 6 min per nonviolator,
ii/ 14 min per paper (PCV) violator.

Note that these time values assume that only 1 min is required to stop a truck. This implies that a squad set up at a temporary location is flagging trucks down rather easily. In the case of an area inspector, he is more likely to patrol the road for suspects and so would require more than 1 min for the truck stopping function of the inspection. Therefore, when staffing level = 1:

i/ the unit processing time per nonviolator increases from 6 to 10 min; and
ii/ the unit processing time per paper violator increases from 14 to 18 min.

We have thus allowed the area inspector an extra 4 min, and a total of 5 min to stop a truck.

Recall from Section 2.4 that the method used for dealing with irregular truck arrivals involves the variation of unit processing times with volume. Therefore, the unit processing times calculated above will be augmented by an amount dependent on the truck volume level. As volume increases, the probability of an immediate* truck arrival increases, thereby reducing the waiting time between arrivals, and thus reducing the amount of time by which our original unit processing times are increased. An example might serve to clarify this relationship.

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*Immediate is defined for this purpose as a 30 s time interval.

Assume that, in the case of regular truck inter-arrivals, the unit processing time for a certain truck category equal 10 min flat. There is no time loss in terms of having to wait for trucks to arrive at any relevant volume. However, once irregular arrivals are considered, we calculate for each volume the probability of one or more truck arrivals in any 30 s time period. For volumes of 10, 25, 50, and 100, this probability is 0.08, 0.188, 0.341, and 0.565 respectively. From these we can derive the average waiting time between truck arrivals for each volume. This idle time, in minutes, equals 6.26 for V = 10, 2.66 for V = 25, 1.47 for V = 50, and 0.88 for V = 100. Note that as V increases, the average waiting period decreases.

The time values generated here are now added to the original 10 min value to create new unit processing times. The final values are, in minutes, 16.26, 12.66, 11.47, and 10.88 for volumes of 10, 25, 50, and 100, respectively. An important observation is that the difference between the unit processing time for regular arrivals and the lowest irregular arrival is large (10 vs. 16.26), while the difference between regular arrival and the highest irregular arrival is quite small (10 vs 10.88). This supports the notion that irregular traffic flow is a critical factor at low volumes only.

Table 4 shows the unit processing times for each of the two truck categories and for each of the chosen volume levels.

Since processing time is required in some of the formulae to be used in the calculations, we will represent this variable by the symbol T and an appropriate subscript to differentiate between truck categories.

Total hourly volume of trucks inspected (V_i) is found by using the formula:

$$V_i = (60.HCI) \div [T_p.F_e.I_p) + (T_n.\ (1-F_e.I_p)\ )] \qquad (4)$$

where F_e = inspector's expertise factor
HCI = number of HC inspectors
I_p = paper infraction rate
T_n = non-violator unit processing time
T_p = paper violator unit processing time
$D < 1$

Number of paper violating trucks detected hourly is:

$$D_p = F_e \cdot I_p \cdot V_i \tag{5}$$

Number of non-violating trucks detected hourly is:

$$D_n = (1-F_e \cdot I_p)\ V_i \tag{6}$$

Time (in minutes) required to process paper-violating trucks detected hourly is:

$$T_p \cdot F_e \cdot I_p \cdot V_i \tag{7}$$

Time (in minutes) required to process non-violating trucks detected hourly is:

$$T_n \cdot (1-F_e \cdot I_p) Vi \tag{8}$$

The only other calculation needed involves the derivation of the expected hourly number of both paper violators and nonviolators in the truck population. These values are a function of infraction rate and volume.

Expected hourly number of paper-violating trucks is

$$E_p = I_p \cdot V \tag{9}$$

Expected hourly number of non-violating trucks is

$$E_n = (1-I_p)V \tag{10}$$

The symbol V stands for average hourly truck volume on the roadway.

The two ratios which together form the backbone of this analysis are now readily derived as follows:

i/ Inspection capacity, or the ratio of hourly volume inspected to average hourly truck volume, is V_i/V = Equation 4 divided by V.

ii/ Detection efficiency, or the ratio of hourly detected paper infractions to hourly expected paper infractions, is D_p/E_p = Equation 5 divided by Equation 9. (See qualification underscored on p.27.)

3.2/ Graph Interpretation

At this point, various relationships can be plotted by making use of both given and calculated variables.

The graphs presented here are useful in the estimation of specific outcomes. Given a value on either axis, one can determine the value on the other axes which corresponds with a specific curve derived from a set of relevant assumptions. For example, the graph in Figure 6 can be used to solve the following problem. We wish to know the maximum roadway truck volume which can be handled while retaining at least a 30% level of inspection capacity when I_p = 0.08 and staffing level equals three. Simply read across from where the vertical axis equals 0.3 over to the curve derived from the specified assumptions and down to the horizontal axis. The required value equals approximately 78. Therefore, we can say that up to a volume of or about 78, three inspectors should be able to process at least 30% of all trucks for paper inspection when the infraction rate is no higher than 8%.

Alternatively, the problem above can be posed and solved in a reciprocal manner. Given a specific level of V, one can determine the expected inspection capacity for the given set of assumptions.

In addition to this single curve analysis, other questions can be answered by a comparison of curves (solid vs. dotted, or solid vs. solid, or dotted vs. dotted). All these methods have in fact been used for the

basis of the observations made here. For example, the difference between solid and dotted curves in the Figure 6 graph is the sole function of a change in infraction rate from 0.08 in the solid curves to 0.15 in the dotted ones. Again, actual values for either curve can be read from the axes to give a quantitative measure of the variation caused in inspection capacity (or in the truck volume which can be handled at a given capacity level) due to a change in the infraction rate.

When considering the remaining graphs, it would be useful to approach their analysis in the manner described here. In this way, the numerical values derived and the relationships exposed should be clear and meaningful.

3.3/ Efficiency Charts

Figures 6 through 10 are a series of graphs which reveal efficiency levels, each from a different perspective. They are also useful in the exposition of the direction and degree of influence associated with the influencing variables.

The basic points revealed in each graph are presented below.

3.3.1/ Figure 6 Observations

In Figure 6, the graph plots the relative measure of inspection capacity against average truck volume. The major observations to be made are as follows.

- As volume increases there is a rapid decline in inspection capacity followed by a levelling off.

  Example:

  Assuming I_p = 0.08, one area inspector with (detection expertise factor) F_e = 2 can process 34% of trucks on the road when V = 10 but only 9% when V = 50.

- By increasing the staffing level of the inspection unit, there is a substantial increase in inspection capacity which is proportionate except in the case of increase from one to two men.

  Example:

  Assuming I_p = 0.08 and a truck volume of 25 units per hour, the lone area man with F_e = 2 can process 17% of the traffic while a three man team of similar detection ability can handle 76%).

- As infraction rate increases, there is some reduction in inspection capacity.

  Example:

  Assuming V = 50 and three inspectors with F_e = 2, 41% of trucks are processed when I_p = 0.08 but only 36% when I_p = 0.15.

This is explained by the fact that violating trucks take longer to process. The inspector(s) is (are) able to handle less trucks per time period as the infraction rate rises. Note that decreasing inspection capacity does not in itself imply a decreasing violator detection rate. We shall see later that detection efficiency increases as inspector's expertise level increases and inspection capacity decreases.

3.3.2/ Figure 7 Observations

In Figure 7 the graph plots relative inspection capacity against staffing level. Here, the only major observation not already revealed in Figure 6 is that as the (inspector's expertise factor) F_e increases, there is a reduction in inspection capacity.

Example:

Assuming V = 50 and there is a paper infraction rate of 8% two inspectors can process 27% of trucks when their F_e = 2 and 26% when it is increased to 3.

An inspector having a greater expertise level is able to detect more violators and, since trucks in the violator category take longer to process, he will process fewer vehicles in a given time period. Despite this reduction in capacity, it will be shown that there is a corresponding increase in detection efficiency.

Decreasing inspection capacity as V rises, and increasing capacity as staffing level increases has already been shown in the previous graph (Figure 6). Note, however, that these relationships are presented differently in this graph.

There is one final point worthy of mention about this graph. It involves the comparison of different levels of the expertise factor (F_e = 2 for solid curves vs. 3 for dotted curves) for various levels of V. Note that as volume decreases and staffing level increases, the gap between each pair of solid and dotted curves is reduced and finally eliminated in two of the three cases. The V = 25 curves provide the best example of this behaviour. The gap between the solid and dotted curve in each pair represents the amount by which inspection capacity is reduced due to a rise in the inspector's expertise level. Now, as the number of detections approaches the number of violations on the road (either because of lower V or increasing staffing level), the factor of detection expertise becomes less obvious and less critical. When the number of detections comes to equal the number of violations on the road, the two curves join. Beyond this point, no level of increase in detection expertise will matter since the inspector(s) cannot detect more violators than exist.

3.3.3/ Figure 8 Observations

In Figure 8, inspected truck volume (an absolute measure of inspection capacity) is plotted against staffing level. The major points are as follows:

- With the addition of more inspectors, the number of trucks inspected per time period increases.

  Example:

  When V = 25 and the (paper infraction rate) I_p = 0.08%, one inspector with (expertise factor) F_e = 2 can process 4.3 truck units per hour, while three men, having a similar level of expertise, process 18.96 units).

- As average truck volume increases, the inspected volume increases.

  Example:

  With an 8% infraction rate, two inspectors with (expertise factor) F_e = 2 can process 9.28 trucks per hour when V = 10, and 12.07 trucks when V = 25.

This increase is substantial only to a certain threshold, at which point, average truck volume reaches a level where no matter how much higher V rises, the number of trucks which an inspection unit can process will not increase. This point is illustrated in the Figure 8 graph where the gap between each successively higher V curve decreases, indicating that the number of trucks inspected increases at a lower rate.

- As the inspector's expertise factor increases, volume inspected decreases.

  Example:

  When V = 50 and the (infraction rate) I_p = 0.08 two inspectors with (an expertise factor) F_e = 2 will process 13.72 units per hour while two men with F_e = 3 will inspect 12.78 trucks.

As explained earlier, as more violators are detected due to increasing expertise, the volume of total trucks inspected must decrease.

3.3.4/ Figure 9 Observations

In the Figure 9 graph, the detection efficiency measure is plotted against average truck volume. Three major trends are revealed.

- As V increases, detection efficiency decreases rapidly and then levels off.

  Example:

  With (paper infraction rate) I_p = 0.08 one man with (expertise factor) F_e = 2 has a detection efficiency of 35% when V = 10, but only 10% when V = 50.

Since the number of expected violators (the denominator in our efficiency measure) increases as V rises, the ratio of detected to expected violators must decrease.

- As staffing level increases, detection efficiency increases markedly.

  Example:

  When V = 50 and (infraction rate) I_p = 0.08 an area man with (expertise factor) F_e = 2 has a detection efficiency of 19% while a three man crew has an 82% efficiency.

- As the inspectors' expertise level increases, detection efficiency increases substantially.

  Example:

  When V = 25 and (infraction rate) I_p = 0.08 an area man with F_e = 1 has a detection efficiency of 18% whereas when F_e = 2, efficiency jumps to 34%.

This graph supports the notion that an inspector's experience and expertise is a tremendously valuable influence in the inspection process. The

well experienced inspector is probably the most powerful exponent of a successful inspection activity.

3.3.5/ Figure 10 Observations

In the Figure 10 graph, the detection efficiency measure is plotted against the rate of paper infraction. The only observation not already shown in Figure 9 is that, as the paper infraction rate increases, detection efficiency decreases.

Example:

When V = 25 and the (expertise factor) F_e = 2, a two man crew has a detection efficiency of 97% when I_p = 0.08 as opposed to 87% when I_p rises to 15%.

Again, this trend can be explained by the fact that as I_p rises, the expected number of violators also rises.

3.4/ General Observations

This completes our discussion concerning the efficiency charts for this scenario. Interpretation of the results derived from these graphs, especially in the case of numeric values, should be done carefully. Keep in mind that, since the operational time values used as the basis for the analysis are at best average values, any results should be allowed the possibility of some variation from the actual value. All efforts have been made during the course of the analysis to keep the aspect of variability at a minimum. But the existence of this factor, in an activity which is variable by its very nature, must be recognized and accepted. Despite this limitation, it is believed that the trends observed are correct, and that the numerical values derived are approximately representative of the efficiency levels which they are intended to reveal.

4/ SCENARIO #2 -- PAPER AND WEIGHT CHECK

In this operation, weight enforcement is included with the basic paper check of Scenario #1. Again, there is no motor vehicle inspection included. In terms of manpower, although an HC area man could conduct this inspection, it is most likely that at least two and often three or four inspectors are employed in one unit. The weighing of a truck on a set of portable scales is quite difficult for only one officer to manage. As such, the single man unit conducts this activity less often. Even for two or more officers, the weighing function is a rather difficult operation which very often entails some wasted time, usually as a result of driver error in aligning the truck up onto the scales.

On average, a 3 S2 type truck is assumed. Therefore three weighings are required, one for the front single axle and two for the dual-axle units. Assume that 3.3 min are required for weighings per truck and 1.3 min for axle spacing measurements.

The following four possible situations give rise to four truck categories, each with its own unit processing time:

i/ Paper and Weight Violator

Function	Time (minutes)
stop vehicle	1.0
visual check	2.0
paper check	2.0
PCV write-up	8.0
axle unit weighings (3)	3.3
axle spacing measurement (4)	1.3
HTA write-up	15.0
between-inspections break	1.0
TOTAL TIME	33.6

There is a slight variation in the case of the lone area inspector. The "stop vehicle" function time rises to 5, giving a total unit processing time of 37.6 min.

ii/ Paper Violator only

Function	Time (minutes)
stop vehicle	10
visual check	20
paper check	2
PCV write-up	8
axle weighings (3)	3.3
between-inspections break	1.3
TOTAL TIME =	17.3

Again, the "stop vehicle" function should be modified in the case of one inspector to yield a 21.3 min unit processing time.

iii/ Weight Violator Only

Function	Time (minutes)
stop vehicle	1.0
visual check	2.0
paper check	2.0
axle weighings (3)	3.3
axle spacing measurements (4)	1.3
HTA write-up	15.0
between-inspections break	1.0
TOTAL TIME =	25.6

For the one man unit, total time equals 29.6 min.

iv/ Non-violator

Function	Time (minutes)
stop vehicle	1.0
visual check	2.0
paper check	2.0
axle weighings (3)	3.3
between-inspections break	1.0
TOTAL TIME =	9.3

When staffing level equals one, total time equals 13.3 min.

It should be noted that in cases (ii) and (iv) above, the "axle spacing measurements" function could be added to create two more, slightly different, situations. However, since each measurement takes so little time, and since in many cases only two of the possible four measurements are taken, these two slight variations are not considered here.

The total process of this scenario is presented schematically in Figure 11. Each box in the diagram represents a function which may take place in this operational situation.

The assumptions required for the analysis are:

i/ irregular truck inter-arrivals (see Section 2.4 for a complete explanation of the method used);

ii/ regular violator inter-arrivals;

iii/ no motor vehicle inspection involved; and

iv/ detection rate is a function of both the infraction rates (paper and weight) and the inspector's level of detection expertise.

The parameters and their associated values are:

i/ average hourly truck volume is V = 10, 25, 50, 100;

ii/ number of highway carrier inspectors is HCI = 1, 2, 3, 4;

iii/ paper infraction rate is I_p = 0.06, 0.10, 0.20;

iv/ weight infraction rate is I_w = 0.06, 0.10; and

v/ inspector's expertise factor is F_e = 1, 2, 3.

In addition to these five, one other variable is used as a paper and weight violation dependency factor. Partial dependence between paper and weight violation is assumed and could be established by field observation. However, it can be treated here theoretically by the factor α,

where $\alpha > 1$. The probability of paper violation among trucks with weight violation is α times. It will be shown that this variable has no influence on efficiency, at least over the value range used here. Until this measure can be refined, α should be set equal to 1 in the calculations.

4.1/ Calculations

The unit processing time for each of the four truck categories has been presented earlier in this section. As explained in Section 2.4 and as implemented in the first scenario, the method used to handle the problem of irregular truck inter-arrivals is used in this case also. The unit processing times developed on the basis of regular arrivals with no waiting time are now modified at each level of V in order that they may reflect the amount of idle time which might be faced during the course of inspections.

Table 5 shows the refined unit processing time values for each of the four truck categories for the case of a two-, three-, or four-man mobile squad unit.

Total hourly volume of trucks inspected (V_i) is found by the formula:

$$V_i = (60.HCI) \div [(T_{pw}.F_e.\alpha.I_p.I_w) + (T_p.F_e.I_p\ (1-\alpha\ I_w)) + (T_w.F_e.I_w\ (1-\alpha.I_p)) + (T_n\ (I-F_e.I_p-F_e.I_w + \alpha.F_e.I_p.I_w))] \qquad (11)$$

where: F_e = inspector's expertise factor
HCI = number of highway carrier inspectors
I_p = paper infraction rate
I_w = weight infraction rate
T_n = non-violator unit processing time
T_p = paper violator unit processing time
T_{pw} = paper and weight violator unit processing time
T_w = weight violator unit processing time
α = paper and weight violation dependency factor (assume = 1)
$D <$ 1

Number of paper and weight-violating trucks detected hourly:

$$D_{pw} = F_e \cdot \alpha \cdot I_p \cdot I_w \cdot V_i \quad (12)$$

Number of paper-violating trucks detected hourly:

$$D_p = F_e \cdot I_p (1-\alpha \cdot I_w) V_i \quad (13)$$

Number of weight-violating trucks detected hourly:

$$D_w = F_e \cdot I_w (1-\alpha \cdot I_p) V_i \quad (14)$$

Number of non-violating trucks detected hourly:

$$D_n = (1-F_e \cdot I_p - F_e \cdot I_w + \alpha \cdot F_e \cdot I_p \cdot I_w) V_i \quad (15)$$

In order to find the amount of time required to process each of the four truck category volumes detected hourly, simply multiply the expressions in Equations 12 through 15 by their corresponding processing time (T) value.

The expected hourly number of each of the four truck types is calculated as follows:

Expected hourly number of paper and weight-violating trucks:

$$E_{pw} = \alpha \cdot I_p \cdot I_w \cdot V \quad (16)$$

Expected hourly number of paper-violating trucks:

$$E_p = I_p (1-\alpha \cdot I_w) V \quad (17)$$

Expected hourly number of weight-violating trucks:

$$E_w = I_w (1-\alpha \cdot I_p) V \quad (18)$$

Expected hourly number of non-violating trucks:

$$E_n = (1-I_w - I_p + \alpha \cdot I_p \cdot I_w) V \quad (19)$$

Note that V stands for hourly average truck volume on the roadway and should not be confused with the similar symbol V_i which stands for hourly truck volume inspected.

Having calculated the volume inspected, and the number of detected violations and expected violations, the next step is to derive the ratios which serve as the measures of efficiency for our purposes:

i/ Inspection capacity, or the ratio of hourly volume inspected to average hourly truck volume is V_i/V = Equation 11 divided by V.

ii/ Detection efficency, or the ratio of hourly detected infractions to hourly expected infractions, is calculated for each violating category:

a/ paper and weight detection efficiency is D_{pw}/E_{pw} = Equation 12 divided by Equation 16;

b/ paper detection efficiency is D_p/E_p = Equation 13 divided by Equation 17, and

c/ weight detection efficiency is D_w/E_w = Equation 14 divided by Equation 18.

All the above calculations have been performed for each possible combination of specified parameter values.

4.2/ Efficiency Charts

The calculated values can now be presented more meaningfully in the form of graphed relationships between pairs of variables. Refer to Section 3.2 for a discussion concerning a suggested method for the analysis of the graphs developed.

Following is a listing of the major points to be drawn from each of the graphs presented in Figures 12 through 16. The reader is advised these graphs have not been verified by field data.

4.2.1/ Figure 12 Observations

The Figure 12 graph plots the relative inspection capacity measure against average truck volume. The essential observations are as follows.

- As roadway truck volume rises, inspection capacity decreases dramatically.

  Example:

  When $I_p = 0.10$ and $I_w = 0.06$, two inspectors with (expertise factor) $F_e = 2$ can process 63% of all trucks when V = 10, but only 16% when V rises to 50).

- As staffing level is increased, inspection capacity rises proportionately.

  Example:

  When V = 25, $I_p = 0.10$, and $I_w = 0.06$, two inspectors can handle 30% of traffic while four men can handle 62%, if (the expertise factor) $F_e = 2$ in both cases.

- As the paper and weight violation dependency factor α is varied, there is no influence on inspection capacity. This constancy is revealed in the graph by the fact that the dotted curves representing an $\alpha = 3$ value overlap perfectly with their corresponding solid curve which represents $\alpha = 1$. There is apparently no resulting change in level of efficiency as the level of dependence between the two types of violation is varied -- at least over the range of α used here. An empirical approach to this relationship might be more useful, at least in terms of establishing the incidence of dual (paper and weight) violation. Set α equal to 1 in any of the formulae in which it is found.

4.2.2/ Figure 13 Observations

In the Figure 13 graph, inspection capacity is plotted against the inspector's detection expertise level. The only relationship here not

observable from the previous graph (Figure 12) is that as the detection expertise factor (F_e) is increased, there is a small decrease in inspection capacity.

Example:

When V = 50, I_p = 0.10, and I_w = 0.06, two officers with F_e = 1 can process 18% of trucks while two men with F_e = 3 can handle only 14%.

This inverse relationship may appear illogical, but is easily explained by the fact that violating trucks take longer to process. The more experienced inspector detects more violators and therefore will be able to process fewer trucks in total in a given time period. A subsequent graph will show that as the expertise level rises, detection efficiency rises as a greater proportion of violators are caught. It is important to realize the difference between capacity and efficiency as measured here, and that their behaviour in response to a certain influencing variable need not necessarily correspond.

The trends of decreasing inspection capacity as V rises and increasing capacity as staffing level rises have already been elaborated on in the Figure 12 graph. These relationships are presented in this case from a different perspective and as such may be useful in a supplementary role to reinforce the nature of the trends.

4.2.3/ Figure 14 Observations

Example:

The Figure 14 graph plots inspection capacity against one of the two infraction rates (paper). The major observation here is that as the infraction rate increases, there is a small decrease in inspection capacity.

Example:

When V = 25, and I_w = 0.06, two inspectors having (detection expertise factor) F_e = 2 can process 30% of all trucks when I_p = 0.10, but only 27% when I_p rises to 0.20.

The explanation for this is similar to that given above for decreasing capacity due to a rising detection expertise level. In either case, the absolute number of detected violations increases, and since violators require a longer processing time, inspection capacity must decrease as the numerator (V_i) of this measure becomes smaller.

The fact that inspection capacity decreases as V rises and that it increases as staffing level rises is also evident in this graph. These trends have already been elaborated on.

4.2.4/ Figure 15 Observations

In the Figure 15 graph, the detection efficiency measure is plotted against V (truck volume on the roadway). Note that the curves are identical for each of the three violator categories. There are three important relationships to be extracted here.

- As V rises, detection efficiency decreases dramatically.

  Example:

  When the infraction rates are 0.10 and 0.06 for paper and weight respectively, two inspectors with (a detection expertise factor) $F_e = 2$ are able to detect 60% of all violators when V = 25, but only 17% when V rises to 100.

- As more inspectors are added to the squad, detection efficiency increases substantially and proportionately except in the case of increase from one to two men.

  Example:

  When V = 50, $I_p = 0.10$, and $I_w = 0.06$, two inspectors having (an expertise level) $F_e = 2$ should detect 32% of all violators while four officers of similar ability should detect 64%.

- As the detection expertise factor (F_e) increases, detection efficiency rises substantially and proportionately except in the case of increase from one to two men.

Example:

When V = 25, I_p = 0.10, and I_w = 0.06, two inspectors with F_e = 1 or no significant expertise should detect 33% of all violators while two experienced men with F_e = 2 should detect 60%).

The inspector's ability to judge which trucks are likely candidates for paper, weight, or any other type of violation, and those which are not violators, is a critical factor in the mobile inspection process.

That the curves derived in this graph are identical for each of the three violating categories is explained by the fact that the "inspector's expertise factor", F_e, was applied equally for paper as for weight detection. In reality, it may be that an inspector has a greater success rate in the detection of one of these two violation types. If this were the case, F_e would have to take on different values for each type of detection rather than being applied uniformly. The detection efficiency curves would then be different for each violation type since expertise level is one of the factors affecting detection rate.

4.2.5/ Figure 16 Observations

The Figure 16 graph plots detection efficiency against one of the two infraction rates -- paper. The major point to be drawn from these curves is that as infraction rate increases, detection efficiency decreases somewhat.

Example:

When V = 25, and I_w = 0.06, two inspectors with (expertise factor) F_e = 2 will detect 60% of all violators when I_p = 0.10 but only 54% when I_p climbs to 0.20.

Note that the curves are again identical for each violation type because of the uniform application of F_e to paper and weight detection.

The variable on the horizontal axis is that of the paper infraction rate, but, substituting weight infraction rate in its place would lead to a similar relationship with detection efficiency.

The trends of decreasing detection efficiency due to increasing volume, and increasing efficiency due to a rise in staffing level, have already been presented but are evident in this graph also.

This completes the analysis of the efficency charts developed for this scenario.

4.3/ General Observations

As in the paper check only scenario, care should be taken in interpreting the information presented in the graphs. One should realize that the results derived in the analysis are based on a series of assumptions, and so are relevant only for one particular combination of assumptions and parameter values. This point is especially true for numerical values. General relationships and trends between variables are less constrained by many of the assumptions and parameter valuations.

The variability in operational time values for the various functions performed in this inspection process, allows for an additional and very important source of potential instability in the derived curves. The various numeric values of efficency are, therefore, by no means absolute. They should be regarded as approximate representations of the general range of efficiency which is expected when the underlying operational time values, and assumptions are appropriate and fulfilled adequately.

The "weighing by portable scales" function is one of the most difficult operations to tie down in terms of time requirement. This is a rather difficult procedure, largely due to its highly labour-intensive nature. We have represented it with an average time requirement which is often violated. As such, the derived results must be interpreted as having a good possibility for variation from actual values.

5/ SCENARIO #3 -- MECHANICAL INSPECTION

The mechanical fitness inspection may be appropriately considered as an important element of commercial vehicle regulation. Nowhere does the aspect of road user safety present itself so critically.

This scenario is necessarily developed in a manner different from that used for the other operational situtations. As yet, there has been no attempt to determine the true compliance rate of the mechanical safety regulations for total truck population. As a result, we do not have "expected infraction rate" values in this case. Therefore, "detection efficiency" cannot be determined.

5.1/ Description

The mechanical inspection process is presented schematically in Figure 2.

Mechanical inspection is quite flexible. One or two mechanical inspectors (MVIs) may either work out of a TIS facility or as a mobile unit. In the latter case, the mechanics may accompany highway carrier inspectors (HCIs) to form a combined enforcement team, although this is not common practice. When working out of the TIS facility, the MVIs may either choose a time when the station is operational or when it is not.

Off-road inspection is another alternative. The MVIs often inspect a fleet of trucks at the company's terminal. This method has an advantage of convenience for the inspecting personnel and also provides the trucking firm with a valuable benefit (i.e., MTC mechanics may find defects which might have led to costly and unsafe breakdowns on the road).

These possible variations (of the mechanical inspection process) all have a distinctive processing time associated with them. Any analysis involving this function will thus require that a set process be defined and assumed. For our purposes, the following two variations of the mechanical inspection function should serve as adequate illustrations:

1/ two MV inspectors temporarily working out of a non-operational TIS;

2/ one MV inspector working a specific area (equivalent of a HC area inspector).

Each of these cases could be considered in conjunction with highway carrier inspection, i.e., in (1) above the TIS would be operational and in (2) above the lone MVI would be part of a mixed mobile squad.

Even when the carrier and mechanical inspections are carried out together, they still remain almost separate functions, with only two differences:

i/ In the presence of HC inspectors, MV inspectors may not devote as much time to stopping a truck.

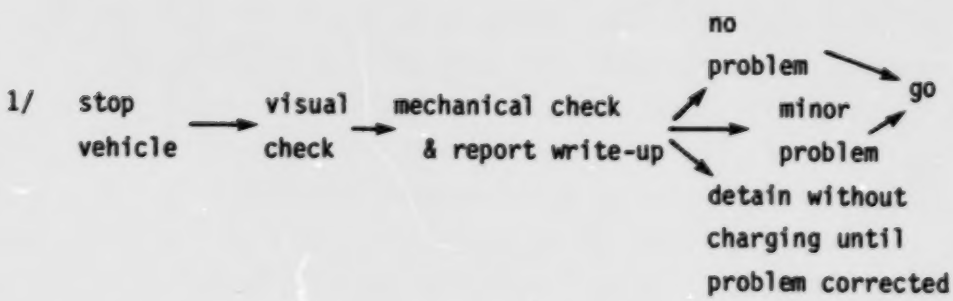
ii/ The HC inspector(s) (and especially in the case of one MVI) in the mobile squad may devote some time to helping the MVI by:

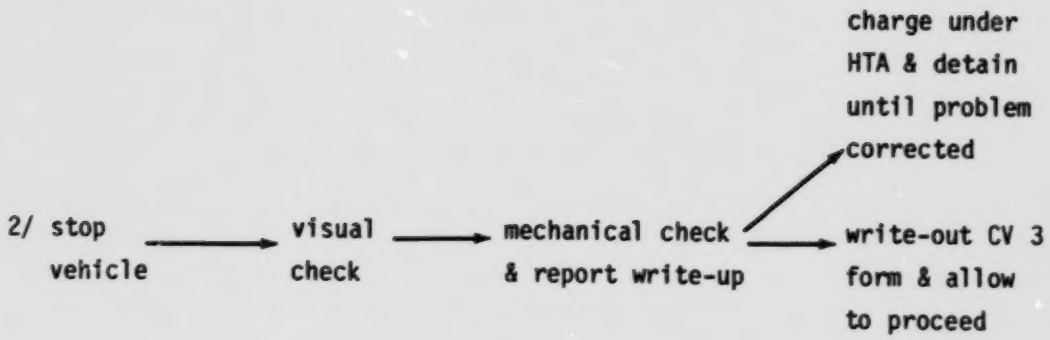
a/ helping write out a mechanical report as the MVI performs checks; or

b/ escorting trucks to a nearby service station to correct any major problems found by the MVI.

The distinction between a mixed (carrier and mechanical) inspection and a purely separate one is evidently quite small. Strictly speaking, however, this scenario deals with the mechanical inspection process, and thus the mixed situation is not considered.

The overall flow chart of the mechanical inspection (Figure 2) can be reduced to two general procedures for the different processing times:





Note that in reducing the general flow chart to the two subcomponents above, the following inspection functions have been neglected:

i/ Escort to nearby service station to correct problem -- This is an infrequent ocurrence.

ii/ Plates removal -- The inspector performs this task immediately if repairs obviously cannot or will not be performed on the spot. Any detained trucks that have not been fixed by shift's end have their licence plates removed.

iii/ Issue NV 29 (red tagging) -- The NV 29 is a red waterproof card, worded "unfit vehicle" indicating that a unit is unfit for road travel. It is hung on the unfit equipment, but only at terminal inspections. Although it has no legal backing, red tagging at terminal inspections is an extremely effective method of improving the mechanical condition of vehicles.

The "CV 3" is a legal form issued in those cases where the MVI feels that the vehicle is currently fit for highway use, but due to the nature or number of defects involved, he wishes to insure that the necessary repairs are made within a specified time. This gives the trucker x days to show up at some MV inspection location with the problem corrected. Breach of this deadline results in an automatic charge under the HTA.

In order to minimize the trucker's inconvenience of sitting in line waiting for re-inspection at the Downsview Lane, the MVI's from Metro-West District have been affixing a notice to the CV 3s. This allows the owner to submit invoices or work orders to the district office as proof that the vehicle has been repaired. Spot checks are performed to maintain credibility. This privilege may be withdrawn when necessary.

Two possible truck types can be defined in this scenario:

- **Not charged**

Function	Time (minutes)	
	2 men at TIS	1 mobile man working alone
stop vehicle	1.0	5.0
visual check	1.0	2.0
mechanical check & report write-up	13.5	20.0
between inspection break	1.0	1.0
TOTAL TIME	16.5	28.0

- **Charged or subject-to-being-charged**

Function	Time (minutes)	
	2 men at TIS	1 mobile man working alone
stop vehicle	1.0	5.0
visual check	1.0	2.0
mechanical check & report write-up	13.5	20.0
either, HTA charge & write-up	(15.0)	(15.0)
or, CV 3 issue & write-up	(4.0)	(4.0)
between inspection break	1.0	1.0
TOTAL TIME HTA:	31.5	43.0
CV 3:	20.5	32.0

Definition of "violation" in this scenario is slightly different from previous cases. We have seen that if a truck is found to be in violation of weight, size or paper regulations, the operator is charged. In the case of an MVI finding a major mechanical problem, however, charging the operator under the HTA is not an automatic consequence. Therefore, it would be erroneous to represent the number of violations detected by the number of charges laid. When a major mechanical problem is found, the

MVI may either charge and detain the truck or he may, very often, detain without charging until the problem is corrected, or issue a CV 3.

It would appear that the "removed from service" category plus the number of CV 3s issued best reflects the number of detected violations. Hence, the rate of detection among inspected trucks is taken as the ratio of "trucks removed from service" plus CV 3s issued, to "total trucks inspected". Note that this detection rate is not necessarily representative of the unknown total population infraction rate. It is highly likely that the population infraction rate is lower than the observed inspected volume detection rate.

The major reason for this discrepancy would be the inspector's expertise factor. As in the case of the carrier inspectors, an experienced MVI can apparently choose trucks so as to maximize the inspection of probable violations. As a result, the detection rate cannot be generalized to represent the population infraction rate.

Unfortunately, since the expected infraction rate for this type of violation is unknown, a quantitative analysis of the type undertaken in the other two major scenarios is impossible. However, if and when this critical parameter is estimated, this scenario could be developed in a manner very much similar to the "paper check only" scenario. One could simply replace paper infraction rate (I_p) with mechanical infraction rate (I_m) and the two unit processing times (one violator and one non-violator category, in either case) with those here, and the formulae would then be applicable to the "mechanical check only" operational situation. Efficiency measures could be calculated and efficiency charts generated for specific situations.

5.2/ Empirical Data

Some empirical data concerning mechanical inspections by district and region is available on a yearly basis. Tables 6 and 7 give available data for the Kingston and Ottawa districts.

Although this is a very restricted sampling of districts, Tables 6 and 7 do exemplify some important points. They support the notion that there

is great variation across the province in terms of the MV inspection process. Between regions, districts, or inspectors, emphasis may be placed on different points. Between inspectors, individuals may be inclined to check those mechanical components that they are most comfortable with, thereby possibly neglecting certain critical areas. The level of uniformity in the inspection of vehicles across the province needs to be improved.

A recent trend in gradually shifting emphasis in terms of inspection location from the primary highways to less major roads is also evident in the two tables above. It can be argued that this trend should be reversed, since the safety threat of unfit vehicles is probably more serious on the more heavily-travelled major routes. This leads to another question: Where can MV inspections be conducted on the major highways without creating safety hazards for motorists and inspectors? Some have suggested service centres, off-ramp locations or shoulder-of-the-road attempts, but these all have their obvious faults. The only logical location seems to be at a TIS facility. Therefore, any attempt to increase MV inspection on major arteries should see an increasing use of fixed station facilities by the MVIs.

If and when total truck population infraction rates for mechanical defects are estimated, the analytical methodology developed in this study may be applied to mechanical inspection. However, the efficiency measures derived from the model would be affected by data input limitations to an even greater extent than the highway carrier inspection functions. Average inspection times may become meaningless when one considers that a truck may have anywhere from two to nine axles. Air-braked vehicles require more time for inspection than hydraulic-braked vehicles. Straight trucks pulling utility trailers consume extra time for inspection of their primary and secondary attachments. In most cases, utility trailers are equipped with electric brakes which are known to be over 50% defective amongst those checked. Therefore, estimation of efficiency as defined principally in this study -- i.e., as the proportion of detected defective trucks to expected defective trucks on the roadway -- would be difficult. Mechanical defect rates are available by:

- o truck type (dump, tank, etc.),
- o vehicle configuration,

- district,
- truck inspection station,
- province or state,
- registered owner, and
- individual MV inspector.

Note, however, that these infraction rates are all in terms of vehicles inspected rather than vehicles travelling on the roadway. Therefore, while detection efficiency per trucks inspected can be calculated, it cannot be for total truck population as of yet.

This concludes our treatment of the mechanical inspection scenario. It is hoped that the qualitative exposition presented here is useful in the understanding of the motor vehicle inspection process.

6/ OTHER SCENARIOS

The three most important and frequently practiced mobile inspection processes have been analysed in this study. The three are, of course, the paper, weight and mechanical checks.

In addition to these, however, there are other possible functions available to the HC inspector(s). Two which have the greatest significance are:

i/ Overall dimensions measurement

This may involve length, height, or width of the truck.

ii/ Check of cargo contents

The contents must be those specified on the bills of lading.

In terms of scenario development, several new combinations of functions could be defined, and a series of other possible operational situations created. Following are the remaining possible inspection processes or scenarios:

a/
- stop vehicle
- visual check
- paper check
- overall dimensions measurement

b/
- stop vehicle
- visual check
- paper check
- cargo check

c/
- stop vehicle
- visual check
- paper check
- weigh using portable scales
- measure axle spacings
- overall dimensions measurement

d/
- stop vehicle
- visual check
- paper check
- weigh using portable scales
- measure axle spacings
- cargo check

e/
- stop vehicle
- visual check
- paper check
- overall dimensions measurement
- cargo check

f/
- stop vehicle
- visual check
- paper check
- weight using portable scales
- measure axle spacings
- overall dimensions measurement
- cargo check

In addition, scenarios (a) through (f) above, the paper only scenario developed in Chapter 3, and the paper and weight scenario developed in Chapter 4 can be combined with the mechanical inspection process to define another eight variations.

Note, however, that despite the rather large number of possible scenarios, the variation between most of them is minimal. The core of any of these "other" situations is simply one of, or a combination of, the three basic scenarios developed earlier. In fact, in analysing the three major operational situations, the remaining scenarios have, to a large extent, also been covered.

Add to the above argument the fact that the functions of overall dimensions measurement and cargo check are infrequently conducted, and there is ample support for their superficial treatment in the study.

The peripheral scenarios defined here would not be commonly practiced -- at least not on a consistent basis. However, the methodology developed in the basic scenarios could be used to handle these special cases by means of slight modification. For example, variations a) through f) are based on either the paper only scenario or the paper and weight scenario. The analytical process of the appropriate basic scenario can also be used for the special case scenario. Since the activity in the special case process, which is the only distinguishing characteristic (e.g., overall dimensions measurement or cargo check), occurs so infrequently, it is unnecessary to consider its infraction rate. Instead, its influence can be incorporated into the formulae by modifying the "unit processing time" value(s). The time requirement of the appropriate function (2 min for overall dimensions measurement or 3 min for cargo check) is added to each unit processing time of the basic scenario. In this way, the special case scenarios can be treated by means of the methodology developed for the basic scenarios.

The one major limitation is the unknown parameter of infraction rate for mechanical fitness. Until this variable is estimated, the MVI process cannot be treated with the method which has been developed for carrier inspection. Infraction rate is required for the calculation of the number of expected infractions. This, in turn, is required for the estimation of detected violations, volume inspected, efficiency measures and, therefore, for efficiency chart development.

The scenarios analysed in-depth in this report (see Chapters 3, 4, 5) represent by far the most common mobile inspection processes. The operational situations presented in this chapter are not actively undertaken as are the basic three, but rather are adopted by the inspector(s) when the situation demands it.

As of October, 1981, a new "operational mode" of inspection has been initiated in the London District. This activity, termed a "local concentrated enforcement initiative", involves an above average number of HCI staff conducting "en masse" inspections. In the first such undertaking at the two Putnam TISs, a total of 15 HCIs were used to man the stations for one shift. Two support vehicles were also used. Staff performed duties on a rotating basis. The support vehicles were used to cover

bypass routes, and other routes for mobile area inspection. Two MVIs were also present. The purpose of such an inspection blitz is to:

> "provoke reports of inspections covering all facets of the various acts and regulations that we enforce... (and) will also allow us to inspect as many vehicles as available manpower will allow with attention also being given to purported empty vehicle traffic using the passing lanes."[1]

If this technique proves successful, and early indications are that it is in terms of report production, it will be used on a regular basis. Adoption of this and/or any other innovative inspection strategy which might result in better enforcement at the regional or district level is certainly welcomed.

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1 W. Carton, District Carrier Inspector, London District in a letter to M.M. McIntyre, D.&V. District Manager, London District, Oct. 16, 1981.

7/ SUMMARY AND CONCLUSIONS

This study was intended to provide:

- an overview of the processes involved in mobile inspection;
- a developed methodology applicable toward the solution of efficiency related questions for specific situations in mobile inspection; and
- an indication of the general efficiency levels to be associated with selected operational situations found in mobile inspection.

This study has succeeded in addressing each of these points in a manner primarily useful to those who will be making use of its contents for purposes of providing the best possible truck inspection system.

The purpose of the derived methodology complete with formulae and graphs is actually two-fold.

Firstly, the calculations and graphs presented serve as approximate representations of the efficiency levels to be associated with the operational situation from which they are specifically generated. Therefore, if one is considering a mobile inspection process as defined in one of the developed scenarios, then the derived results serve as a good indicator of efficiency level. The scenarios developed have been identified as the most commonly occurring mobile inspection processes and, as such, the results of their analysis are useful.

Secondly, and probably more importantly, the calculations and efficiency charts here should be interpreted as being exemplary of a general approach to mobile inspection efficiency estimation. It has been shown that given a set of accurate operational times and appropriate valuation of the parameters, general efficiency levels can be calculated and presented graphically, provided certain assumptions are satisfied. However, as stressed throughout, the operational times, parameter values and assumptions may be highly variable. This variation may be a function of geographic location or time. Therefore, it is suggested that the methodology developed here be applied for specific cases of efficiency estimation where the influencing variables and assumptions can be more narrowly defined.

For example, assume that we wish to estimate the detection efficiency of a specified mobile inspection process for a specific location or route in a certain district. Reliable processing times, accurate measures of average truck volume, relevant infraction rates, the general expertise level of the manpower expected to be used, and a well defined process are required. These values are then plugged into the appropriate formulae, i.e., those from Scenario #1 for a paper only inspection or those from Scenario #2 for a paper and weight inspection. As explained in Chapter 6, the remaining inspection functions can also be accommodated -- except for a MV inspection where infraction rate is unknown. The results can be used to derive efficiency measurement curves in what would now be situation-specific efficiency charts. In such an application, the resulting values would be much more stable than those derived in the scenarios here, since variability during analysis development would be much reduced.

The trends and variable relationships which would be generated in a situation-specific analysis would not be different from those observed in the scenarios of this study. The general trends are summarized in Table 8.

Note that increases in volume or infraction rate (any type) lead to a reduction in both inspection capacity and detection efficiency. These two variables may be seen as net negative contributors to the efficiency of mobile inspection. On the other hand, by increasing the staffing level, both efficiency measures rise. Manpower may be termed a net positive contributor to the efficiency of mobile inspection.

The expertise level variable, F_e, is the only major parameter having a split influence on the two measures. As it rises, inspection capacity decreases while detection efficiency increases. This behaviour has an important implication for the deployment of manpower in terms of experience or detection know-how. Remember that an F_e value of 1 represents an inspector with no detection expertise, i.e., a trainee. As F_e increases from 1, the inspector accumulates more and more expertise. In order to keep the sacrifice of detection efficiency at a minimum, trainees involved in the inspection should be allocated to low volume points

while the more experienced inspectors could handle high V areas -- if it can be proved that experienced inspectors do have significant pre-screening expertise.

The most prominent theme revealed during the course of this study is that of flexibility. This aspect is pervasive in regard to the operational time requirements, the inspection locations, and the inspection process itself.

Average time values for the various functions, which together constitute an inspection process, form the basis of the calculations in this analysis. Although these time values are based on real-world inspections and on the opinions of knowledgeable senior inspectors, the fact remains that there exist many factors which can influence the required processing times.

The human element must be recognized as the main reason for the wide variability in many of the time requirements. For example, theoretically, it should take approximately 3 min 20 s to weigh the three axles units of a 3 S2 truck on a set of portable weigh scales. However, a driver may have difficulty in getting the wheels properly aligned onto the scales, thereby greatly increasing the expected time requirement of this function. This is only one of many instances where the indicated time value is often violated.

As opposed to TIS inspections, where platform scales allow for a more structured and therefore more efficient process, the mobile inspection is dominated by human input. This human input generates benefits on one hand and errors on the other (usually resulting in time loss).

Flexibility results from the fact that one is dealing here with a highly labour-intensive activity. Moreover, the aspect of flexibility is both an asset and a liability. It is a liability in the sense that mobile truck inspection is comparatively less efficient than the fixed station type. However, the flexibility which results in less efficency may simultaneously result in greater effectiveness. Efficiency and effec-

tiveness do not necessarily vary directly. Note that it would be fair to assume that the discrepancy in efficiency between fixed and mobile inspection is a function of differences in infrastructure.

Truckers who knowingly violate may, in fact, perceive the mobile inspection to represent a greater threat to their being detected than do fixed stations. If, for example, a violating trucker hauls over a constant route having one or more TISs which he can by-pass, then the mobile inspection poses the only threat to his being caught. Widespread use of C.B. radio by truckers seems to reduce much of the surprise element of a mobile squad spot check. But, merely having a type of enforcement capable of mobility offsets the violator's natural advantage over fixed inspection stations.

Although the fixed station system has been developed so that much of the province's primary highway network is covered, most other routes are served only by mobile units. Therefore, on such roads, the probability of a violator being detected (both actual and as perceived by the violator) is totally a function of mobile enforcement. Regardless of the efficiency performance of mobile inspection, it nevertheless poses at least a threat of detection to the violator.

Evaluation of the effectiveness of mobile truck inspection must be based on the violator's perception of this form of enforcement. As such, determination of effectiveness is beyond the scope of this particular study.

8/ REFERENCES

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Table 4/ SCENARIO #1 UNIT PROCESSING TIMES

HOURLY TRUCK VOLUME	PROBABILITY OF >1 TRUCK ARRIVALS PER 30 SEC. INTERVAL	AVERAGE WAITING TIME IN MINUTES	UNIT PROCESSING TIMES IN MINUTES			
			AREA MAN *		SQUAD UNIT	
			NON-VIOLATOR	PAPER VIOLATOR	NON-VIOLATOR	PAPER VIOLATOR
REGULAR (ANY VOLUME)	1.000	0.00	10.00	18.00	6.00	14.00
10 IRREGULAR	0.080	6.26	16.26	24.26	12.26	20.26
25 IRREGULAR	0.188	2.66	12.66	20.66	8.66	16.66
50 IRREGULAR	0.341	1.47	11.47	19.47	7.47	15.47
100 IRREGULAR	0.565	0.88	10.88	18.88	6.88	14.88

* Area man assumed to be using cruiser to stop trucks. If area man is flagging trucks at a fixed location (such as in a blitz), use "Squad Unit" processing times.

Table 5/ SCENARIO #2 UNIT PROCESSING TIMES

HOURLY TRUCK VOLUME	PROBABILITIY OF >1 TRUCK ARRIVALS PER 30 S INTERVAL	AVERAGE WAITING TIME IN MINUTES	UNIT PROCESSING TIME IN MINUTES			
			NON-VIOLATOR	PAPER-ONLY VIOLATOR	WEIGHT-ONLY VIOLATOR	PAPER & WEIGHT VIOLATOR
REGULAR (ANY LEVEL)	1.0	0.0	9.3	17.3	25.6	33.6
10 IRREGULAR	0.08	6.26	15.56	23.56	31.86	39.86
25 IRREGULAR	0.188	2.66	11.96	19.96	28.26	36.26
50 IRREGULAR	0.341	1.47	10.77	18.77	27.07	35.07
100 IRREGULAR	0.565	0.88	10.18	18.18	26.48	34.48

As in the case of the paper-only scenario, unit processing time will be represented by the symbol T and an appropriate subscript for each truck category.

Table 6/ MECHANICAL INSPECTIONS BY DISTRICT FOR THE PERIOD 80-04-01 TO 80-12-26

DISTRICT	VEHICLES INSPECTED				
	ROADSIDE			TERMINAL	TOTAL
	TIS	AREA	TOTAL		
KINGSTON	894 (34.7)*	990 (38.4)	1884 (73.11)	693 (26.9)	2577 (100)
OTTAWA	953 (34.6)	1649 (60)	2602 (94.6)	148 (5.4)	2750 (100)

* Bracketed values expressed as a percentage of total vehicles inspected.

Table 7/ SUMMARY OF ROADSIDE MECHANICAL INSPECTIONS BY DISTRICT FOR THE PERIOD 80-04-01 TO 80-12-26

DISTRICT	REMOVED FROM SERVICE			CHARGED UNDER HTA			ISSUED CV 3		
	TIS	AREA	TOTAL	TIS	AREA	TOTAL	TIS	AREA	TOTAL
KINGSTON	149 (52.1)**	137 (47.9)	286 (100)	6 (24)	19 (76)	25 (100)	0 (0.0)	5 (100)	5 (100)
OTTAWA	165 (31.7)	355 (68.3)	520 (100)	12 (11)	97 (89)	109 (100)	38 (28.8)	94 (71.2)	132 (100)

** Bracketed values expressed as the percentage of total for that particular category.

Table 8/ GENERAL TRENDS BETWEEN PARAMETERS & EFFICIENCY MEASURES

RISE IN INFLUENCING VARIABLE	EFFECT ON EFFICIENCY MEASURE	
	INSPECTION CAPACITY	DETECTION EFFICIENCY
truck volume	↓*	↓
staffing level	↑**	↑
infraction rate	↓	↓
detection expertise	↓	↑

*↓ = decrease **↑ = increase

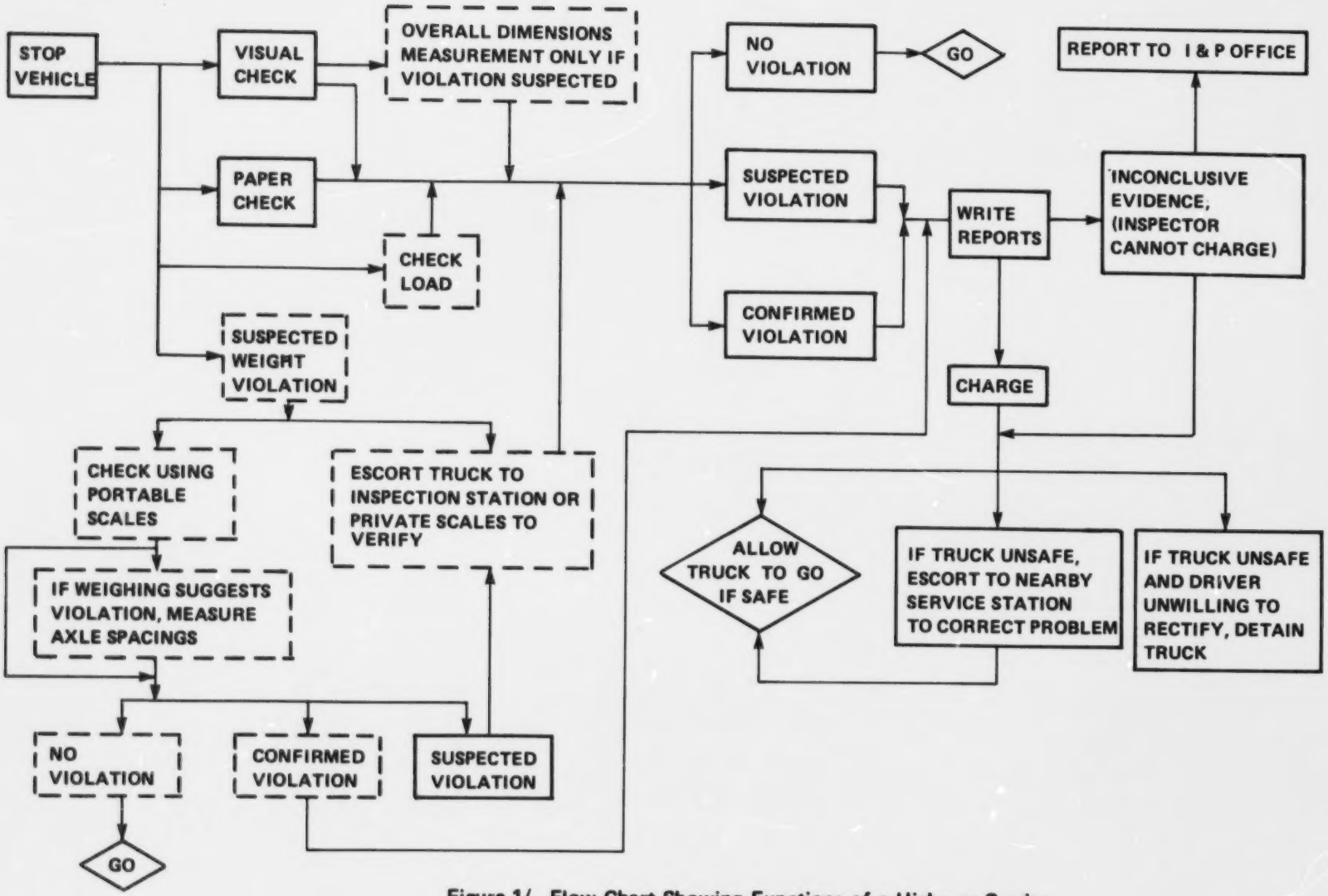

STOP VEHICLE
VISUAL CHECK
OVERALL DIMENSIONS MEASUREMENT ONLY IF VIOLATION SUSPECTED
PAPER CHECK
CHECK LOAD
SUSPECTED WEIGHT VIOLATION
CHECK USING PORTABLE SCALES
IF WEIGHING SUGGESTS VIOLATION, MEASURE AXLE SPACINGS
ESCORT TRUCK TO INSPECTION STATION OR PRIVATE SCALES TO VERIFY
NO VIOLATION
CONFIRMED VIOLATION
SUSPECTED VIOLATION
GO
NO VIOLATION
SUSPECTED VIOLATION
CONFIRMED VIOLATION
WRITE REPORTS
INCONCLUSIVE EVIDENCE, (INSPECTOR CANNOT CHARGE)
REPORT TO I & P OFFICE
CHARGE
ALLOW TRUCK TO GO IF SAFE
IF TRUCK UNSAFE, ESCORT TO NEARBY SERVICE STATION TO CORRECT PROBLEM
IF TRUCK UNSAFE AND DRIVER UNWILLING TO RECTIFY, DETAIN TRUCK

Figure 1/ Flow Chart Showing Functions of a Highway Carrier Area Inspector (1 Man)

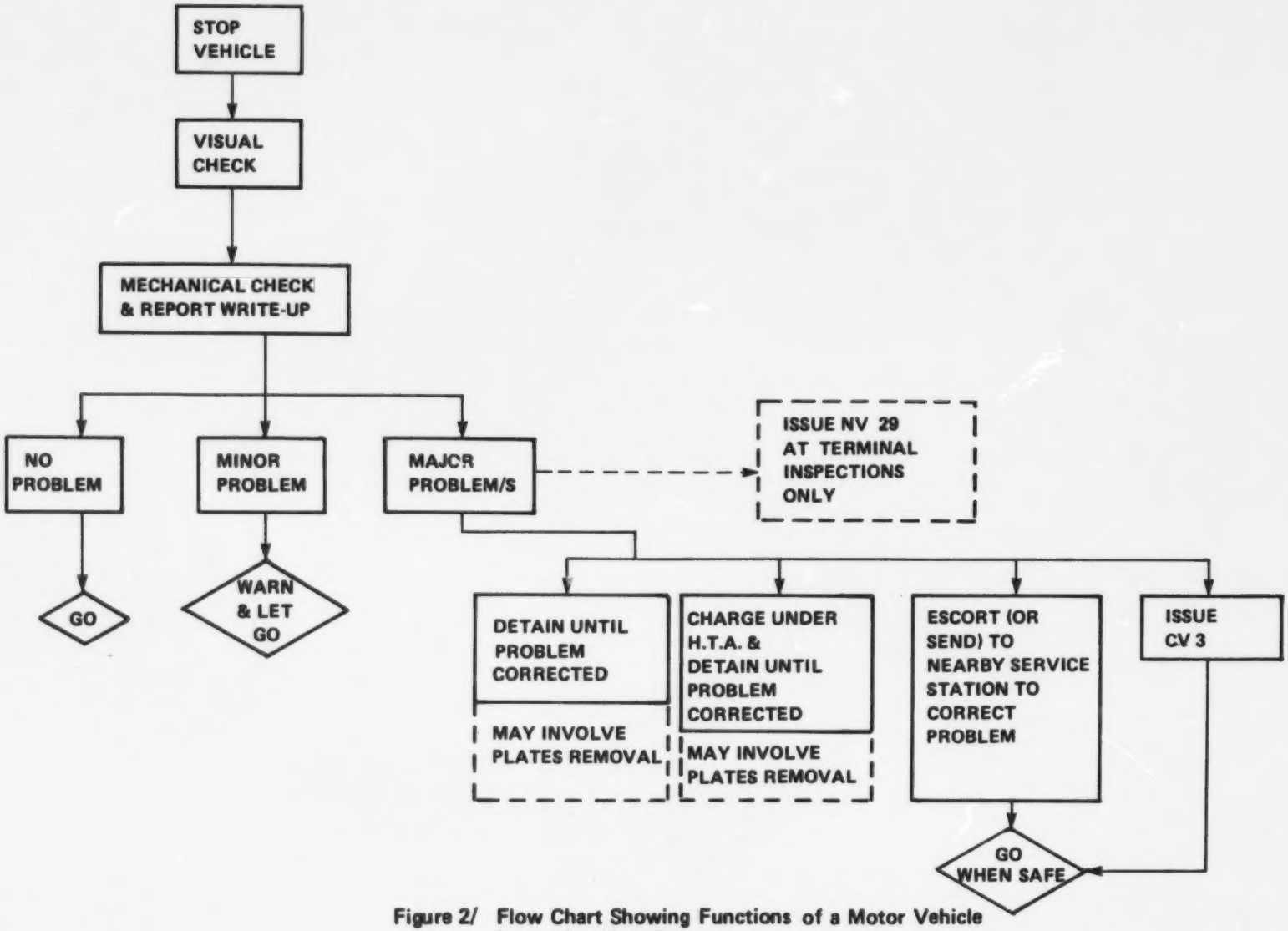


Figure 2/ Flow Chart Showing Functions of a Motor Vehicle Inspection Unit Only

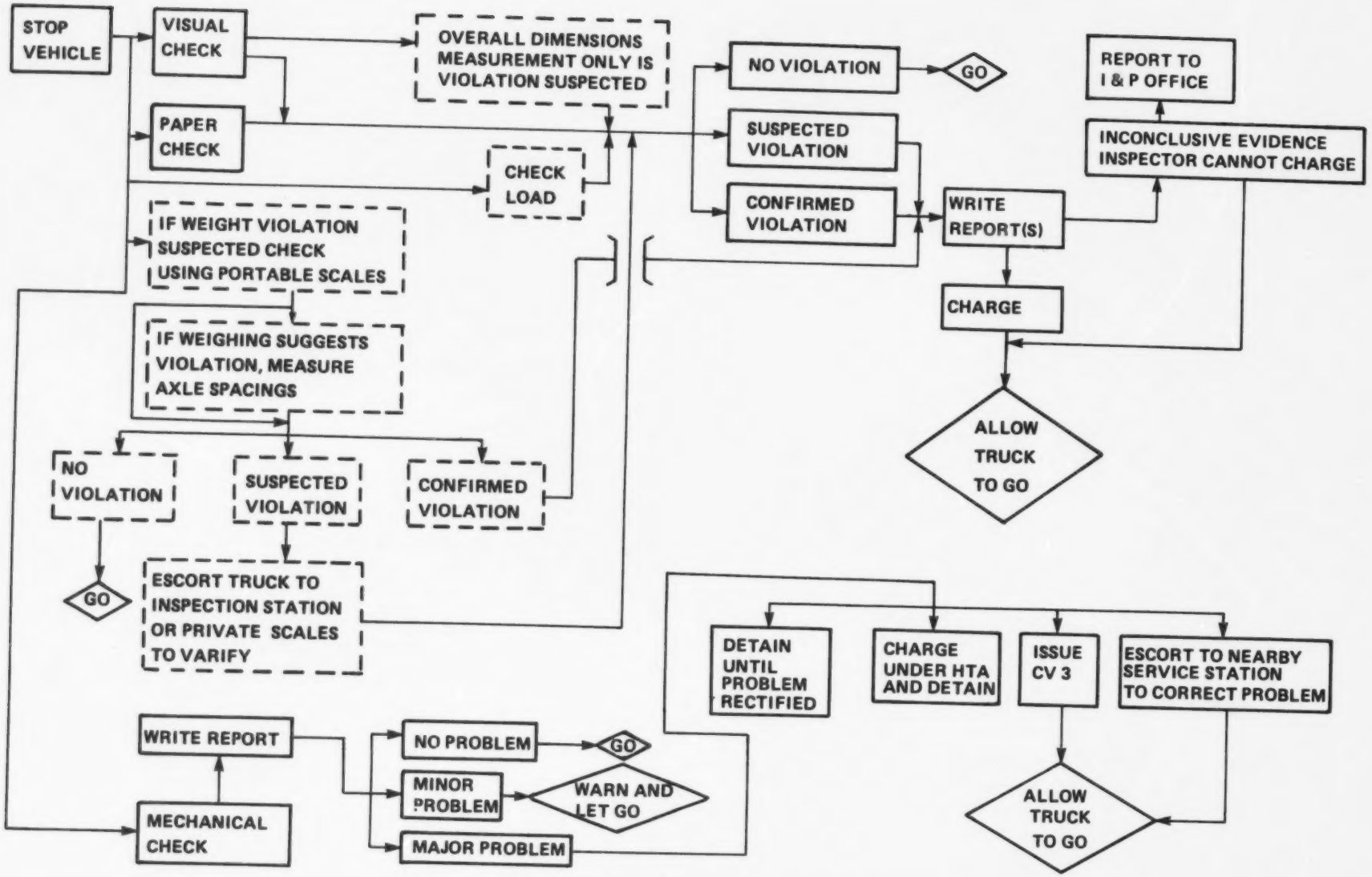


Figure 3/ Flow Chart Showing Functions of a Combined Highway Carrier and Motor Vehicle Inspection Squad

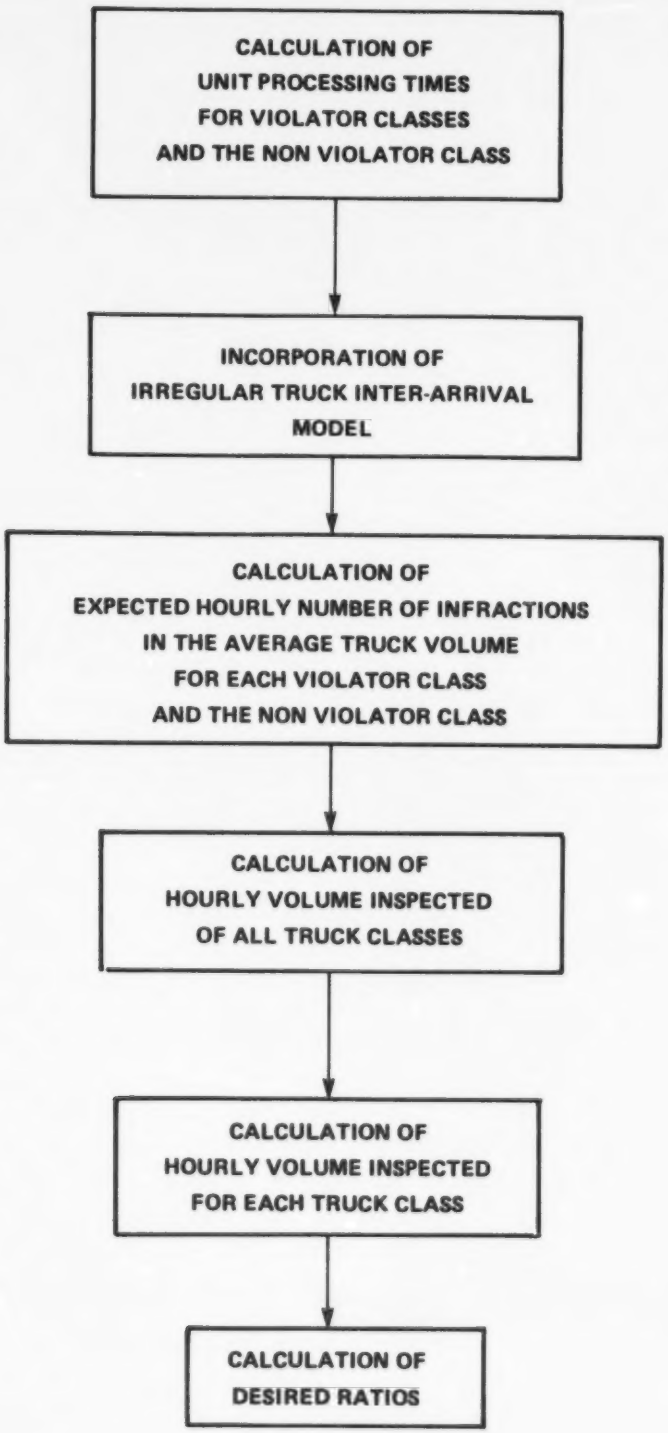


Figure 4/ Analytical Process

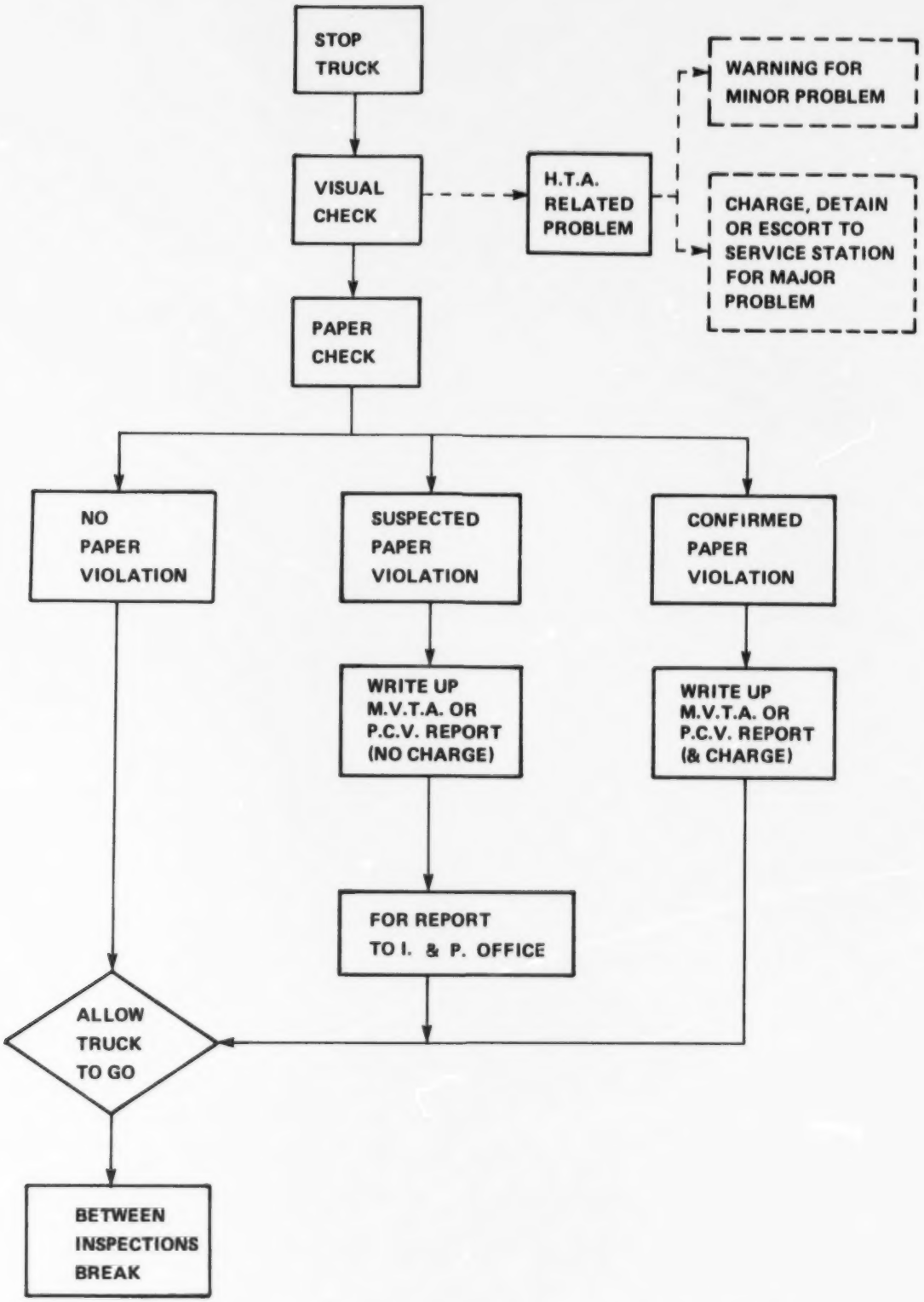
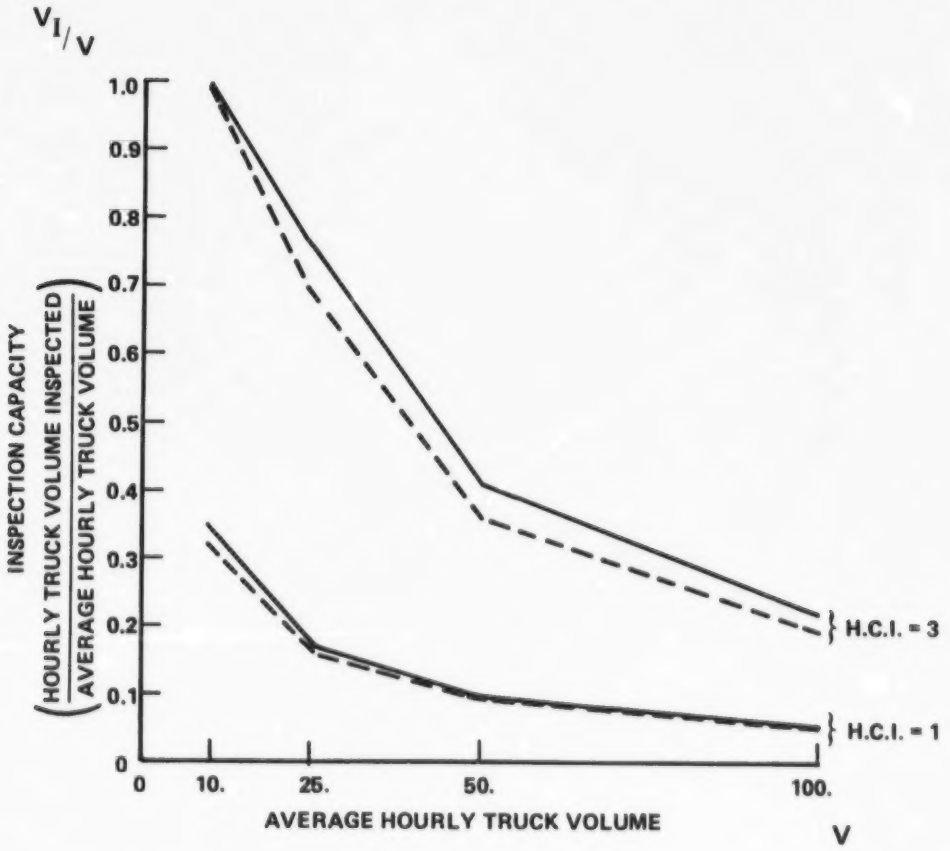

STOP TRUCK
VISUAL CHECK
H.T.A. RELATED PROBLEM
WARNING FOR MINOR PROBLEM
CHARGE, DETAIN OR ESCORT TO SERVICE STATION FOR MAJOR PROBLEM
PAPER CHECK
NO PAPER VIOLATION
SUSPECTED PAPER VIOLATION
CONFIRMED PAPER VIOLATION
WRITE UP M.V.T.A. OR P.C.V. REPORT (NO CHARGE)
WRITE UP M.V.T.A. OR P.C.V. REPORT (& CHARGE)
FOR REPORT TO I. & P. OFFICE
ALLOW TRUCK TO GO
BETWEEN INSPECTIONS BREAK

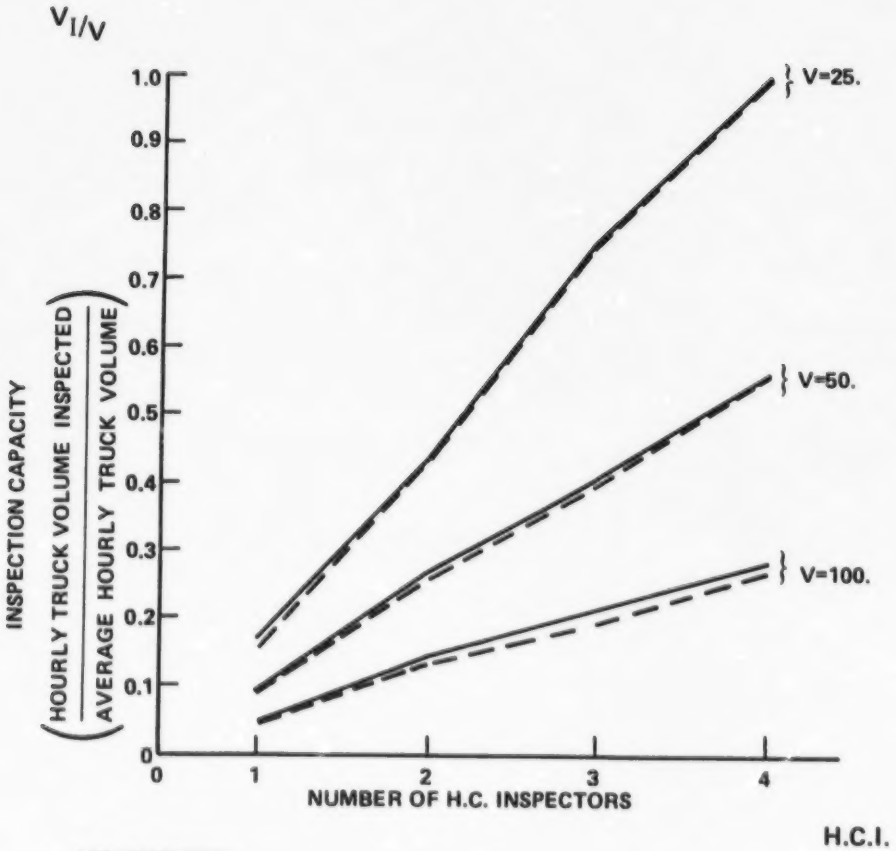
Figure 5/ Flow Chart for Scenario No. 1 – Paper Check Only



ASSUMPTIONS:

- Paper infraction rate = 0.08 in solid curves
- Paper infraction rate = 0.15 in dotted curves
- Inspector's expertise factor = 2.

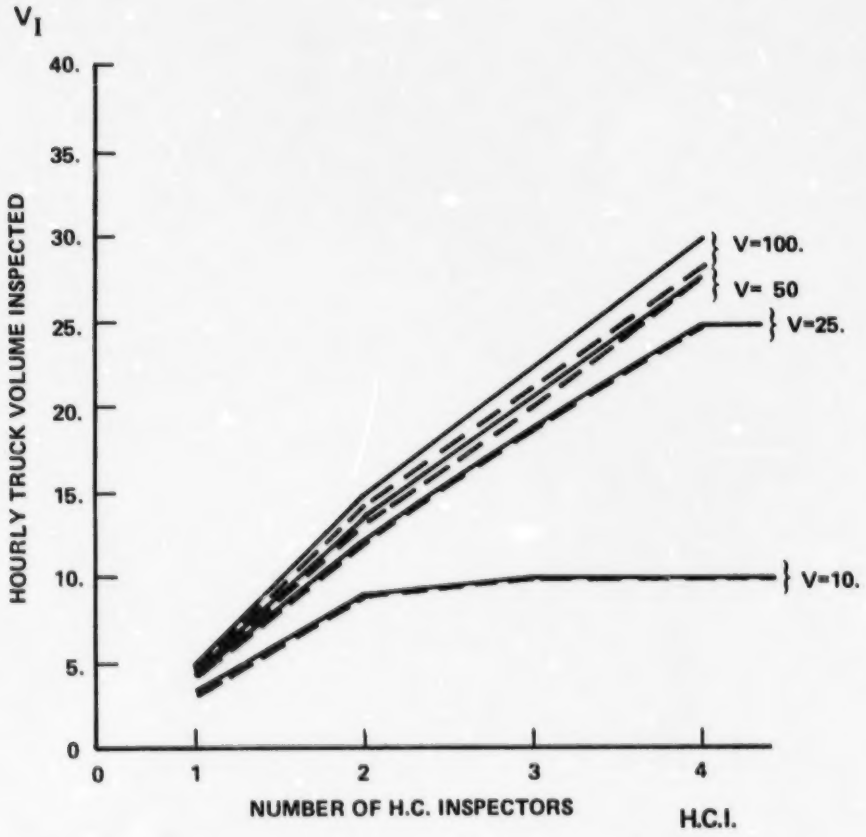
Figure 6/ Relationship Between Inspection Capacity and Average Truck Volume For Paper Inspection Only Scenario



ASSUMPTIONS

- Inspector's expertise factor = 2. in solid curves
- Inspector's expertise factor = 3. in dotted curves
- Paper infraction rate = 0.08

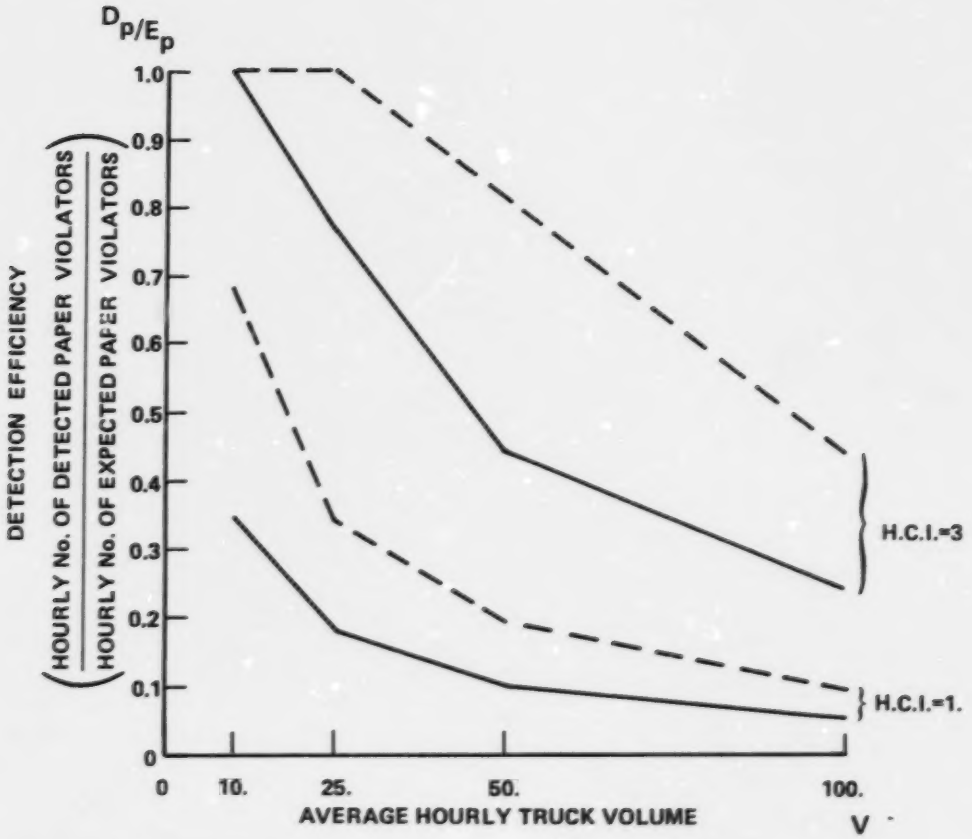
Figure 7/ Relationship Between Inspection Capacity and Staffing Level For Paper Inspection Only Scenario



ASSUMPTIONS:

- Inspector's expertise factor = 2. in solid curves
- Inspector's expertise factor = 3. in dotted curves
- Paper infraction rate = 0.08

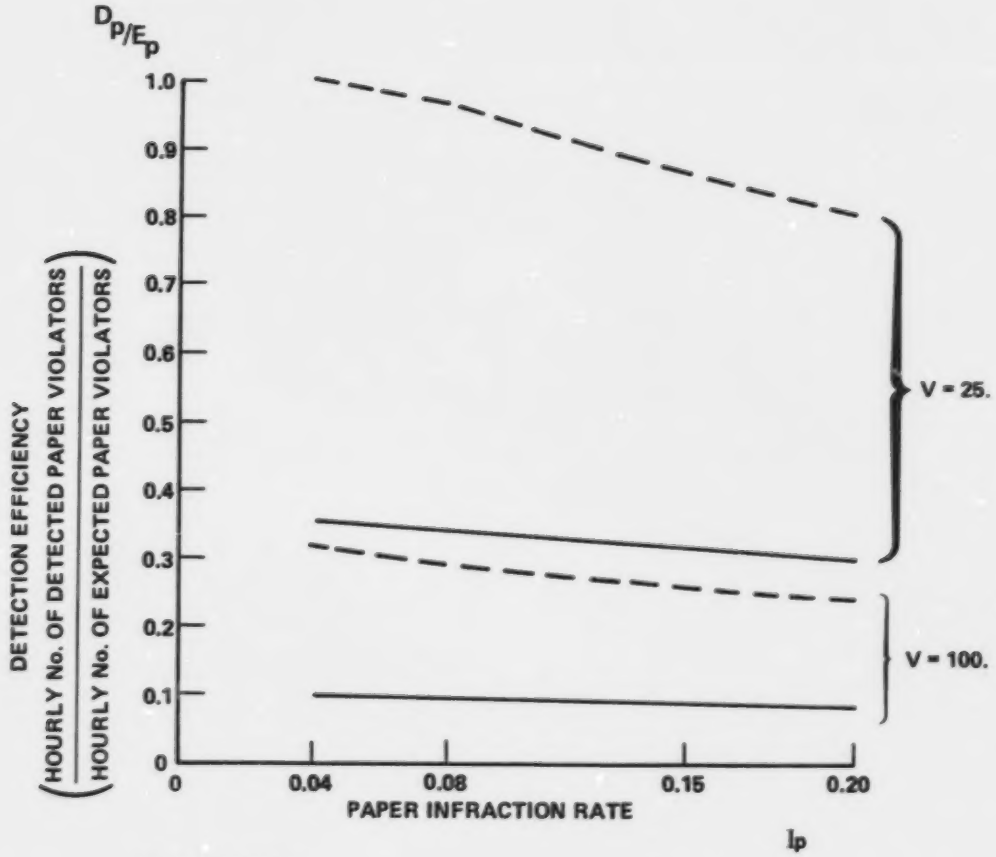
Figure 8/ Relationship Between Number of Trucks Inspected and Staffing Level For Paper Inspection Only Scenario



ASSUMPTIONS:

- Inspector's expertise factor = 1. in solid curves
- Inspector's expertise factor = 2. in dotted curves
- Paper infraction rate = 0.08

Figure 9/ Relationship Between Detection Efficiency and Average Truck Volume For Paper Inspection Only Scenario



ASSUMPTIONS:

- Staffing level = 1 in solid curves
- Staffing level = 2 in dotted curves
- Inspector's expertise fector = 2.

Figure 10/ Relationship Between Detection Efficiency and Infraction Rate For Paper Inspection Only Scenario

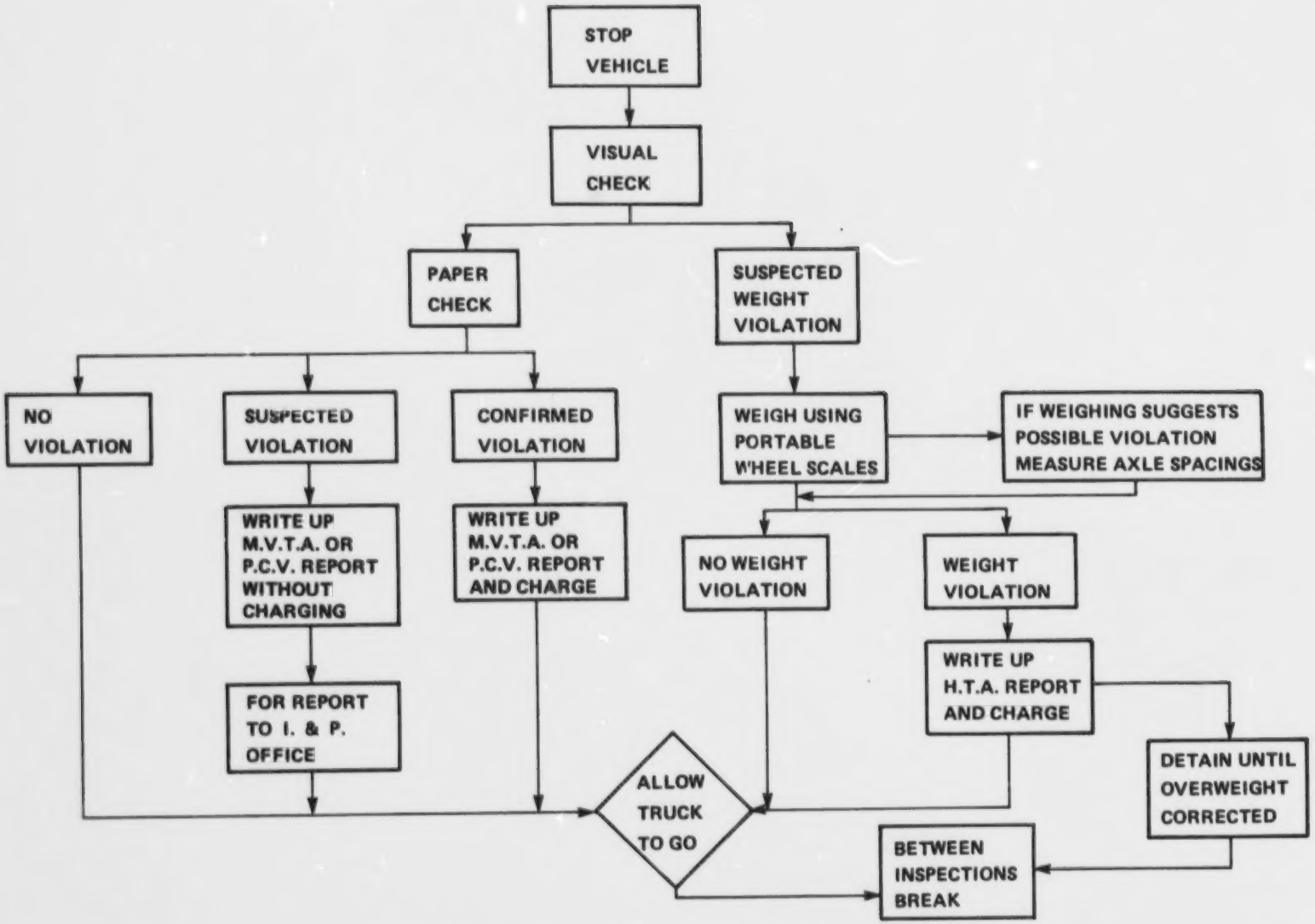
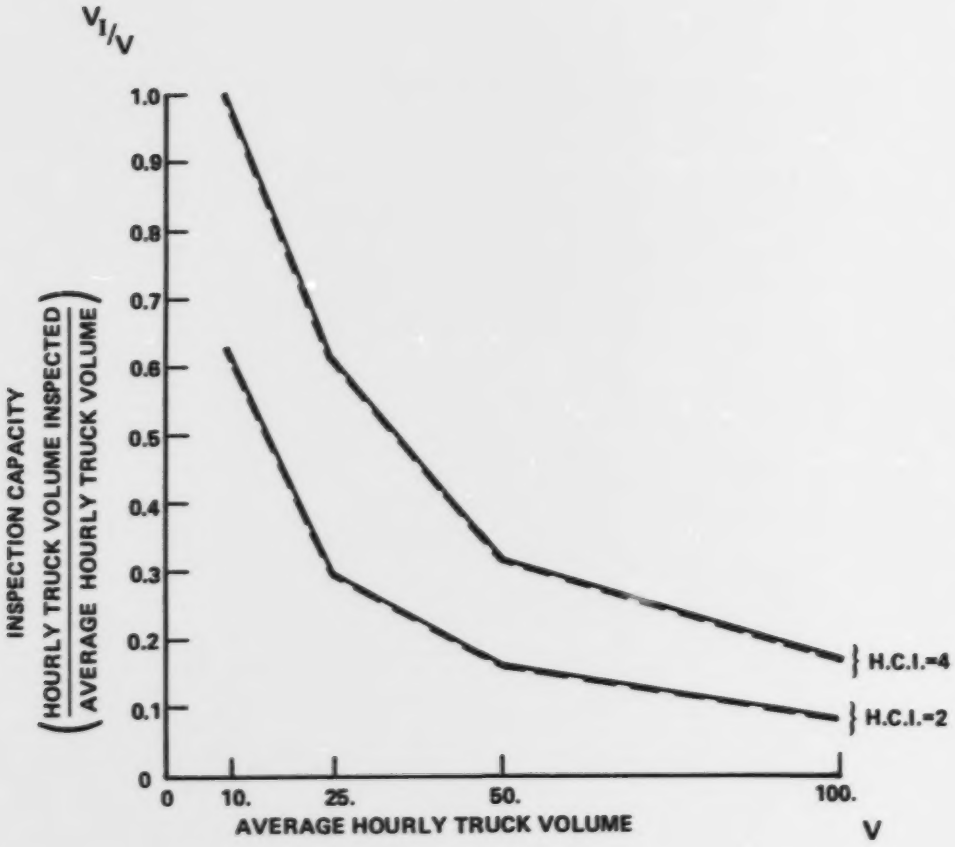

STOP VEHICLE
VISUAL CHECK
PAPER CHECK
SUSPECTED WEIGHT VIOLATION
NO VIOLATION
SUSPECTED VIOLATION
CONFIRMED VIOLATION
WEIGH USING PORTABLE WHEEL SCALES
IF WEIGHING SUGGESTS POSSIBLE VIOLATION MEASURE AXLE SPACINGS
WRITE UP M.V.T.A. OR P.C.V. REPORT WITHOUT CHARGING
WRITE UP M.V.T.A. OR P.C.V. REPORT AND CHARGE
NO WEIGHT VIOLATION
WEIGHT VIOLATION
WRITE UP H.T.A. REPORT AND CHARGE
FOR REPORT TO I. & P. OFFICE
ALLOW TRUCK TO GO
DETAIN UNTIL OVERWEIGHT CORRECTED
BETWEEN INSPECTIONS BREAK

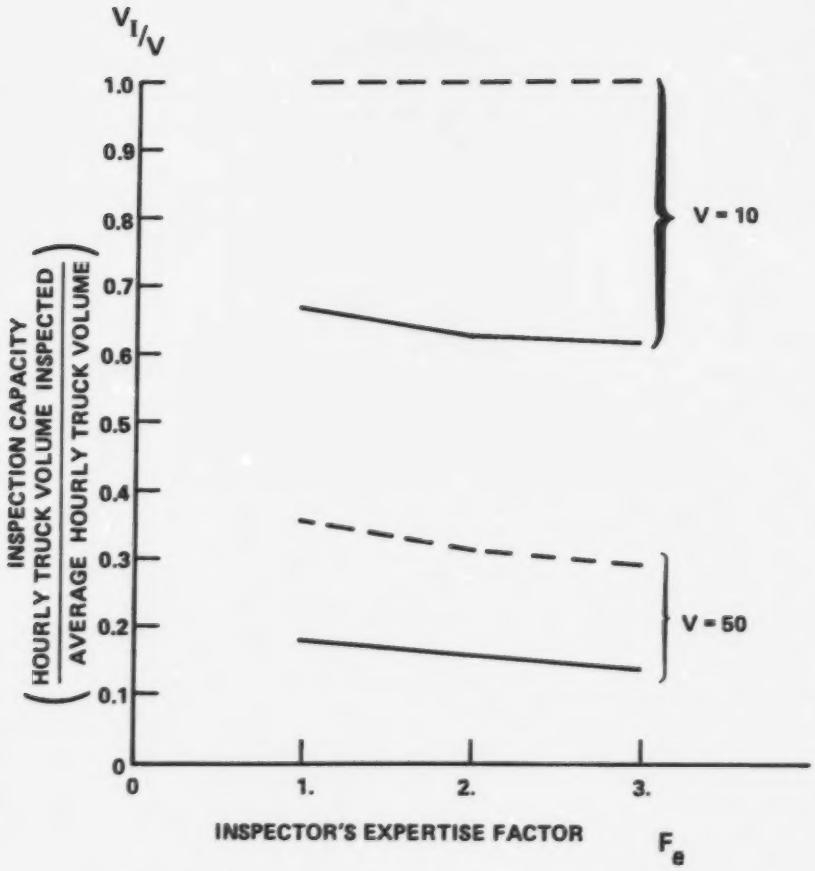
Figure 11/ Flow Chart for Scenario No. 2 – Paper and Weight Check



ASSUMPTIONS:

- Paper & Wt. violation dependency factor = 1. in solid curves
- Paper & Wt. violation dependency factor = 3. in dotted curves
- Inspector's expertise factor = 2.
- Paper infraction rate = 0.10
- Weight infraction rate = 0.06

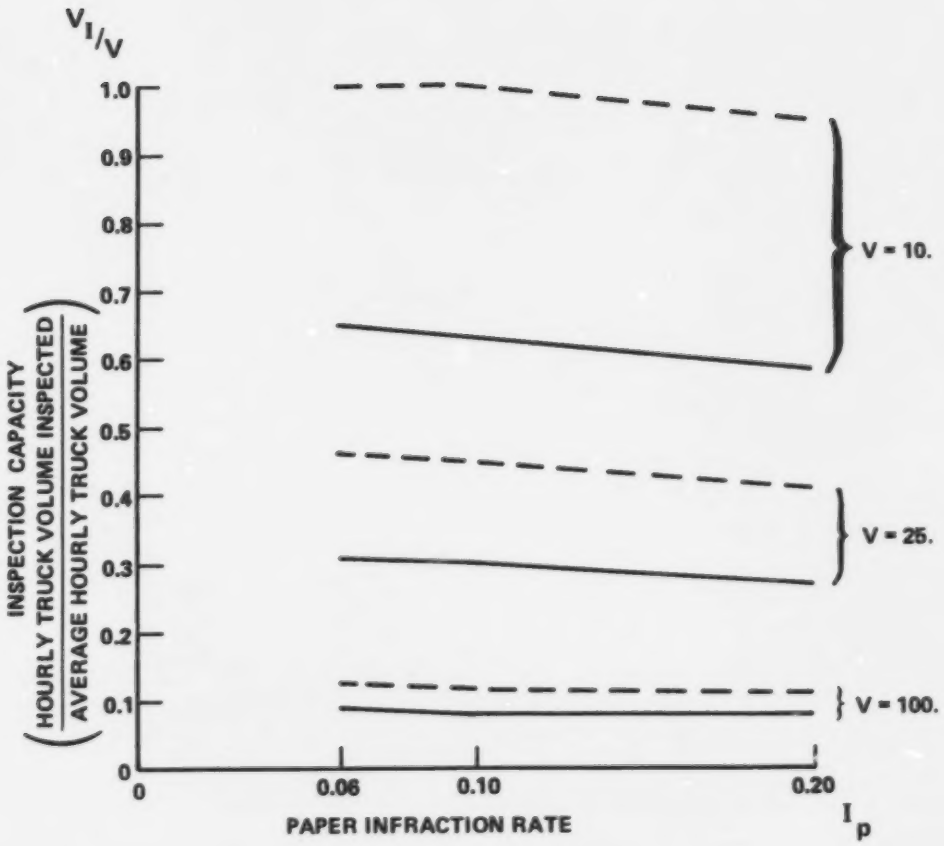
Figure 12/ Relationship Between Inspection Capacity and Average Truck Volume For Paper and Weight Inspection Scenario



ASSUMPTIONS:

- Staffing level = 2. in solid curves
- Staffing level = 4. in dotted curves
- Paper infraction rate = 0.10
- Weight infraction rate = 0.06

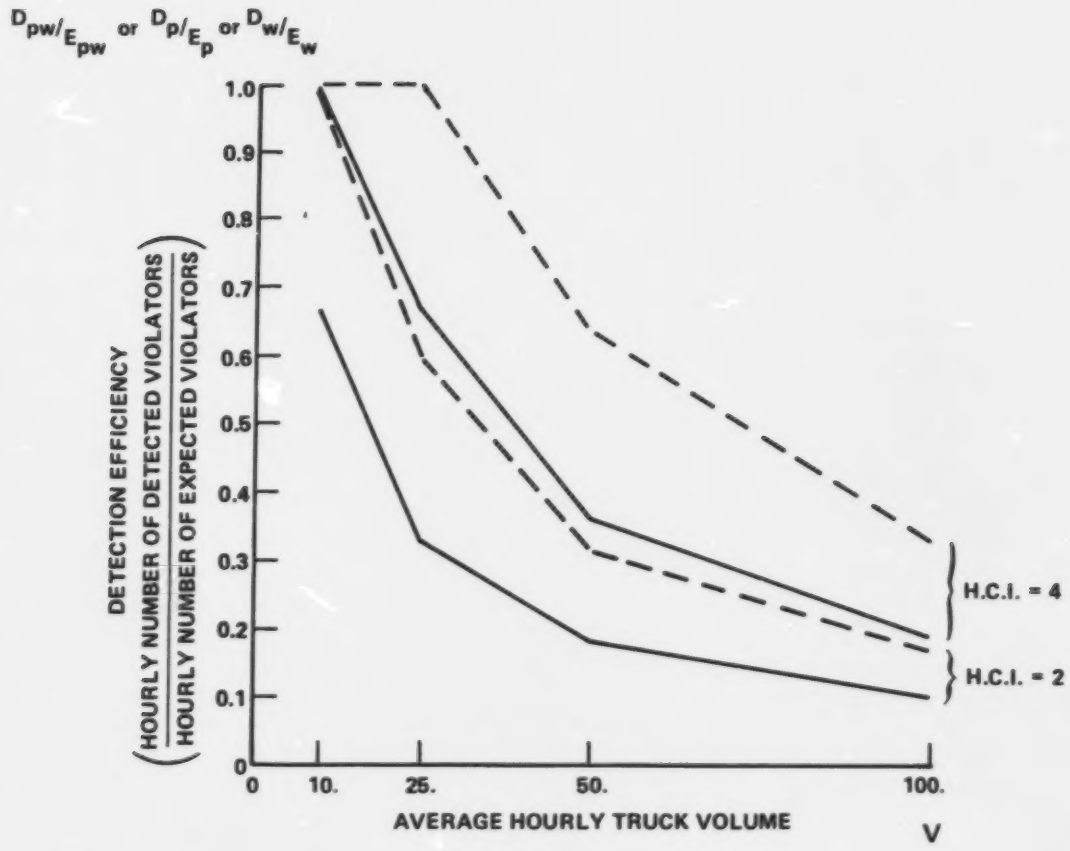
Figure 13/ Relationship Between Inspection Capacity and Detection Expertise For Paper and Weight Inspection Scenario



ASSUMPTIONS:

- Staffing level = 2 in solid curves
- Staffing level = 3 in dotted curves
- Inspector's expertise factor = 2.
- Weight infraction rate = 0.06

Figure 14/ Relationship Between Inspection Capacity (Paper Only) and Infraction Rate For Paper and Weight Inspection Scenario

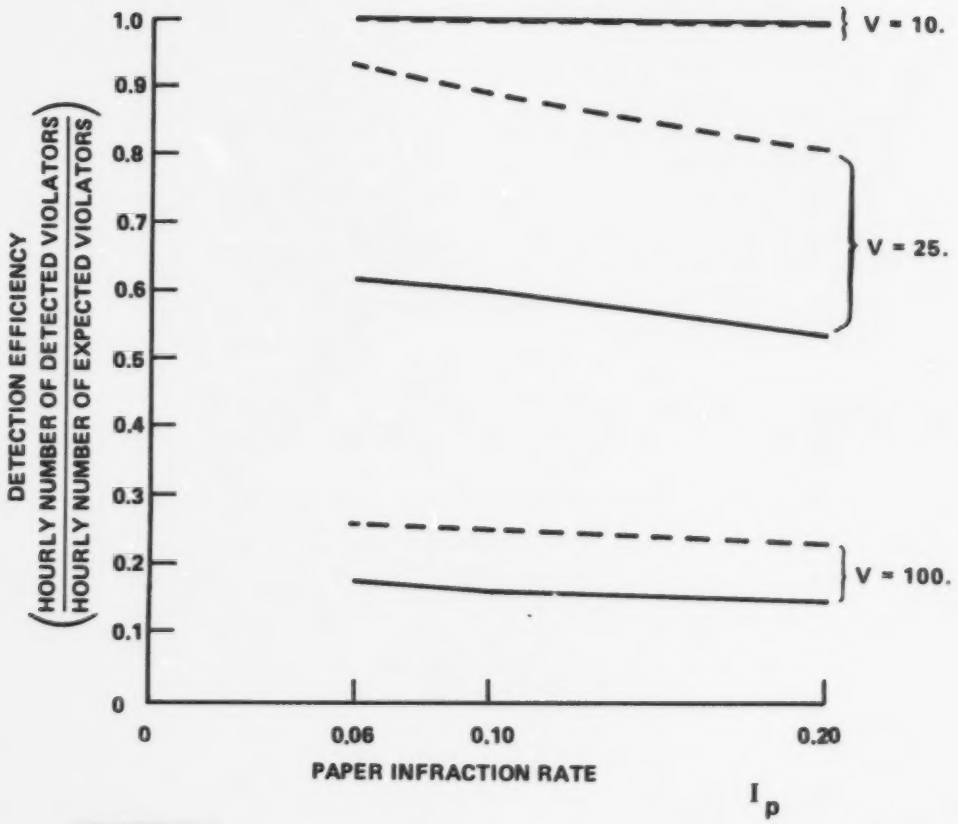


ASSUMPTIONS:

- Inspector's expertise factor = 1. in solid curves
- Inspector's expertise factor = 2. in dotted curves
- Paper infraction rate = 0.10
- Weight infraction rate = 0.06

Figure 15/ Relationship Between Detection Efficiency and Truck Volume For Paper and Weight Inspection Scenario

$Dpw/_{Epw}$ or $Dp/_{Ep}$ or $Dw/_{Ew}$



ASSUMPTIONS:

- Staffing level = 2 in solid curves
- Staffing level = 3 in dotted curves
- Inspector's expertise factor = 2.
- Weight infraction rate = 0.06

Figure 16/ Relationship Between Detection Efficiency (Paper Only) and Infraction Rate For Paper and Weight Inspection Scenario

APPENDIX 1/ COSTS BREAKDOWN FOR MOBILE INSPECTION

Costs presented here are intended as approximations, based on 1980 value terms.

1/ Capital Costs

i/ MTC vehicle used in inspection = $10 000

ii/ Portable Wheel Scales:

a) hydraulic type = $2 400 per pair.

b) electric type = $4 800 per pair.

MTC used the electric type most because they are more accurate, have a digital rather than meter readout, and do not weigh any more than the hydraulic type. The only negative aspect is higher maintenance costs.

2/ Operational Costs

i/ Vehicle:

Assuming a 17.5¢/km operational cost which includes fuel, maintenance, repairs and insurance, and an average distance travelled of 40 000 km/yr, it would cost $7 000 per year to operate one vehicle.

ii/ Inspector's Materials:

Included in this category would be tape measures, various forms, stationery, jig used in the measurement of axle spacings, and uniforms. This is obviously not an important cost component, $500 per year per officer would be a general indication here.

3/ Personnel

This is the single most significant cost element of the mobile inspection process, reflecting the labour intensive nature of this activity. The breakdown is as follows.

i/ District Carrier Supervisor:

- basic salary of $26 375.00 + 18.5% benefits

ii/ Highway Carrier Inspection Officer:

- basic salary of $19 213.00 + 18.5% benefits

iii/ District Motor Vehicle Supervisor:

- basic salary of $24 475.00 + 18.5% benefits

iv/ Motor Vehicle Area Inspectors:

- basic salary of $20 850.00 + 18.5% benefits

Note that a thorough understanding of the cost of personnel requires consideration of support and various levels of managerial staff, e.g., investigating officers and inspecting officers.

Keep in mind that the monetary values presented here are for 1980 and are subject to rapid change.

The provincial totals of the complements for both inspecting and motor vehicles personnel as reported by district managers are listed below.

i/ Mobile carrier inspection:

- 73 inspectors and 83 vehicles,
- 13 district supervisors who also handle TIS enforcement.

ii/ Motor Vehicle Inspection:

- 102 inspectors* and 111 vehicles,
- 11 district supervisors.

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* Excludes 13 inspectors (+1 supervisor) working out of Downsview 401 terminal. These MVIs are not assigned specifically to area inspection of commercial vehicles.

APPENDIX 2/ VIOLATION RATES FOR SPECIAL 1980 SURVEY LOCATIONS

		VIOLATION RATE		
	DIRECTION	OVERLOAD	OTHER	TOTAL
CENTRAL REGION				
SCARBOROUGH DISTRICT				
1. Hwy. 7 & Woodbine	2-way	4.13	7.44	11.57
2. Hwy. 7 & 27	2-way	0	8.24	8.24
3. Hwy. 35 at Hwy. 115	2-way	1.08	8.60	9.68
4. Hwy. 11 at Bathurst	2-way	0	8.00	8.00
MISSISSAUGA DISTRICT				
5. Hwy. 9 (E. of Hwy. 10)	EB only	1.48	4.44	5.93
6. Hwy. 50 (N. of Bolton)	2-way	4.24	4.24	8.48
STONEY CREEK DISTRICT				
7. Hwy. 405, Queenston	WB only	0	8.56	8.56
8. Hwy. 6 Flamboro	NB only	0	5.66	5.66
9. Hwy. 2 at 403, Brantford	WB only	0.26	4.20	4.45
SOUTHWESTERN REGION				
LONDON DISTRICT				
10. Hwy. 2, Thamesford	EB only	0	3.60	3.60
11. Hwy. 3, Courtland	EB only	0	2.63	2.63
WINDSOR DISTRICT				
12. Hwy. 40 (at Hwy. 80)	SB	2.04	10.20	12.24
	NB	8.11	16.22	24.33
KITCHENER DISTRICT				
13. Hwy. 27 (N. of Barrie)	NB	5.26	3.51	8.77
	SB	3.45	6.90	10.35
14. Hwy. 6 (Mount Forest)	NB	1.52	7.58	9.10
	SB	0	6.52	6.52
15. Hwy. 7 (W. of Guelph)	EB	6.25	2.08	8.33
	WB	0	5.44	5.44
16. Hwy. 7 & 8 (E. of Stratford)	EB	0	6.00	6.00
	WB	1.61	3.23	4.84

VIOLATION RATES FOR SPECIAL 1980 MOBILE SURVEY LOCATIONS - CONT'D

		VIOLATION RATE		
	DIRECTION	OVERLOAD	OTHER	TOTAL
EASTERN REGION				
KINGSTON DISTRICT				
17. Hwy. 138 (at Hwy. 43)	NB	13.45	8.40	21.85
	SB	9.92	8.26	18.18
18. Hwy. 16 (S. of Hwy. 43)	2-way	2.99	10.78	13.77
19. Hwy. 31 (at Hwy. 401)	2-way	14.53	7.69	22.22
20. Hwy. 34 (N. of Alexandria)	NB	10.57	8.13	18.70
21. Hwy. 34 (N. of Hwy. 401)	SB	7.83	13.91	21.74
22. Hwy. 37 (at Hwy. 7)	NB	0.88	2.63	3.51
	SB	2.22	4.44	6.66
23. Hwy. 62 (N. of Belleville)	2-way	4.11	0.82	4.93

Reference 3.

APPENDIX 3/ TABLE OF TIME LOSS VALUES

Hourly Truck Volume	Average Waiting Time (Minutes)	Hourly Truck Volume	Average Waiting Time (Minutes)
2	30.12		
4	15.25		
6	10.25		
8	7.75		
10	6.26	56	1.34
12	5.26	58	1.30
14	4.54	60	1.27
16	4.00	62	1.24
18	3.60	64	1.21
20	3.25	66	1.18
22	2.99	68	1.15
24	2.76	70	1.13
25	2.66	72	1.11
26	2.56	74	1.09
28	2.40	75	1.08
30	2.26	76	1.07
32	2.14	78	1.05
34	2.02	80	1.03
36	1.93	82	1.01
38	1.84	84	0.99
40	1.77	86	0.98
42	1.69	88	0.96
44	1.63	90	0.95
46	1.57	92	0.93
48	1.51	94	0.92
50	1.47	96	0.91
52	1.42	98	0.90
54	1.38	100	0.88

The time value corresponding to the relevant volume should be added to the original unit processing times such that the resulting values reflect idle time spent waiting for trucks to arrive.